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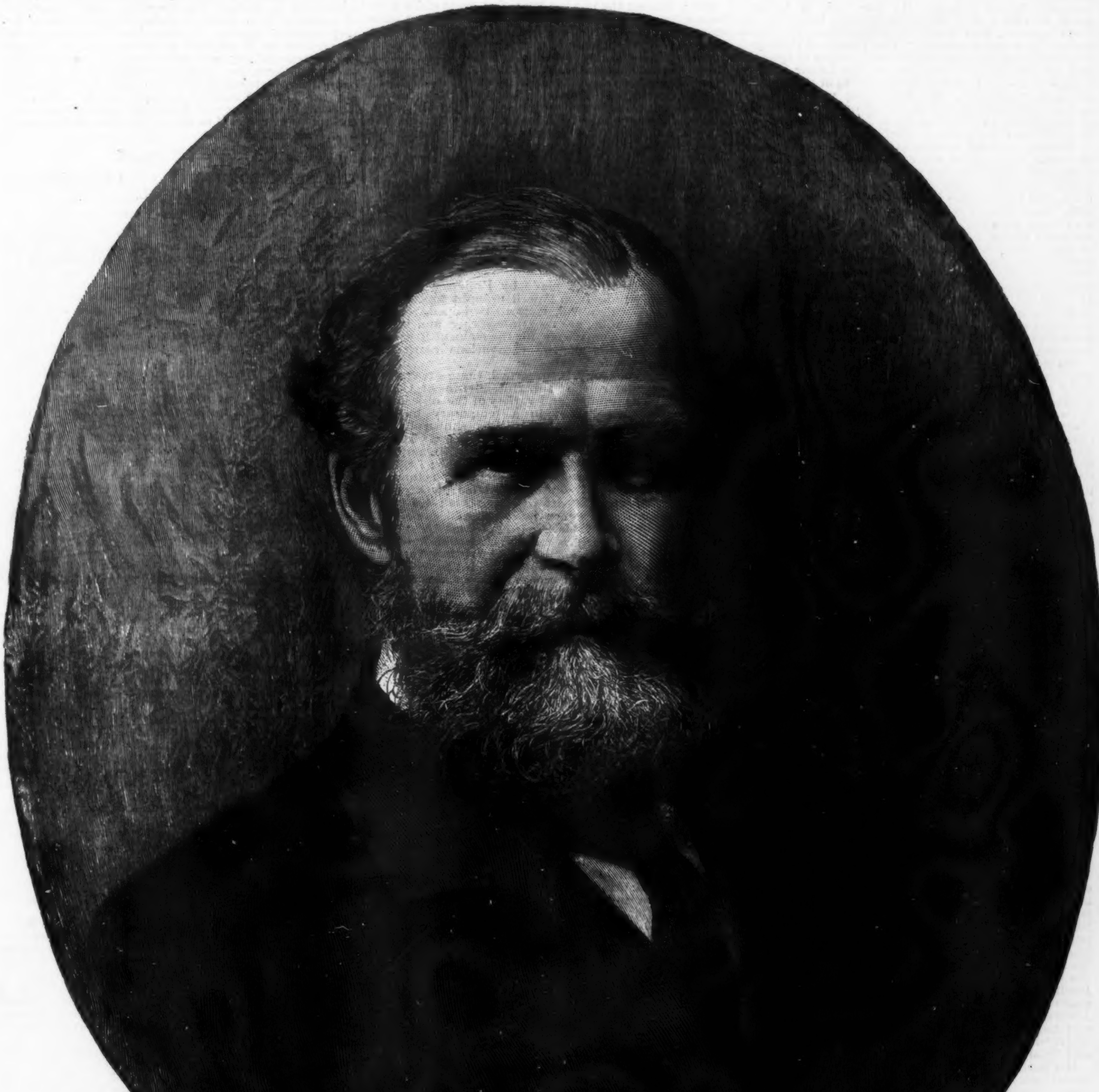


SIR JOHN LUBBOCK.

SIR JOHN LUBBOCK, BART., M.P., F.R.S.

SOME discerning compiler of historical and biographical sketches might easily arrange a volume grouping together a dozen or a score of bankers, Italian, French, Swiss, German, and English, whose literary, scientific, or political accomplishments have won renown. Beginning with Lorenzo dei Medici, we presently think of Roscoe, then of Samuel Rogers, and certainly of Grote, not to mention another contemporary, the late Samuel Sharpe. There is a crowd of English bankers, London and provincial, who were distinguished scholars, though seldom educated at Oxford or Cambridge, and Mr. Goschen is not the first City man who has proved an able minister of finance. Lombard Street is classic ground, as propitious to the studies of poetry, philosophy, and history, to the pursuits of the belles lettres, science, and statesmanship, as the Temple or the official quarter of Whitehall. The subject of our present notice, Sir John Lubbock, Bart., a Fellow of the Royal Society, M.P. for the University of London, is a naturalist, an author, a member of the legislature and a Lombard Street banker. He was born in London, April 30, 1834, son of Sir John William Lubbock, the third baronet, who was a mathematician and astronomer; and whose essay on "The Theory of Probabilities," anticipating some of the calculations of Quetelet and De Morgan, his treatises on the Lunar Theory, on the Tides, and on the Perturbation of the Planets, are highly esteemed. He was many years treasurer and vice-president of the Royal Society. The founder of the family in London, John Lubbock, son of the Rev. William Lubbock, a Norfolk clergyman, rector of Lamas, acquired wealth as a merchant, established the bank, and in 1806 was created a baronet. He was succeeded, in 1816, by his nephew, the second baronet, whose only son, father of the present Sir John Lubbock, was head of the house from 1840 to his death, in 1865. The firm is now styled "Robarts, Lubbock & Co.;" and as a junior clerk in his father's business, at the early age of fourteen, after a few years' schooling at Eton, without the advantage of further academical instruction, John Lubbock commenced his training for City work, passing his leisure time at his father's country house, High Elms, near Farnborough, in Kent. In 1856 he married a daughter of the Rev. Peter Hordern, of Chorlton-cum-Hardy, near Manchester, by whom and his second wife, daughter of General H. Lane-Fox Pitt Rivers, married in 1884, he has several sons and daughters.

His residence in Kent being near that of the late Mr. Darwin, the intellectual curiosity of John Lubbock, in early youth, was powerfully influenced by constant intercourse with the greatest of modern naturalists. He was then led to direct his attention mainly to the structure, habits, and development of insects and of crustacea, becoming a minute observer of wasps, bees, and ants, investigating the fertilization of flowers by the aid of insects, and various problems of comparative zoology in the structure of lower forms of animal life. Some of his researches may be regarded as supplementary to those of Darwin, and were contributed, during many years, to the Transactions of the Entomological and Linnæan Societies and of the Royal Society, and to different scientific journals. He has also lectured on these subjects at the Royal Institution, read papers to the British Association, and written books, such as "The Origin and Metamorphoses of Insects" and "Wild Flowers, considered in Relation to Insects," besides a treatise on "The Thysanura and Collembola," published by the Ray Society. From zoology, in accordance with the tendency of Darwinian doctrine, it was a ready transition to anthropology; and the position of controversy regarding the "Antiquity of Man" led to archæological investigations. Sir John Lubbock therefore examined the famous shell mounds and ancient refuse heaps, irreverently called "kitchen middens," on the coast of Denmark, the human relics in the gravel beds of the Somme, the bone caves of the Dordogne, the lake dwellings built on piles in Switzerland, and the contents of numerous public and private museums, on which he reported in the *Natural History Review*. He lectured at the Royal Institution in 1868 on these subjects, which he has discussed more completely in two important books—"Prehistoric Times, as illustrated by Ancient Remains and the Manners and Customs of Modern Savages," published in 1865; and "The Origin of Civilization and the Primitive Condition of Man," in 1870—works of renown inferior only to those of Darwin for their wide effect on European opinion, having been translated into almost every Continental language, and having gone through many editions. Sir John Lubbock, who has also edited Svend Nilsson's work on "The Stone Age of Sweden," and has written at least sixty or seventy papers for different learned societies, is honored, of course, with numerous distinctions conferred by them. He is F.R.S., ex-president of the Entomological and the Ethnological Societies, and of the Anthropological Institute; has been vice-president of the British Association of Science, of the Royal Society, and of the Linnæan Society; is a Fellow of the Geological Society and the Society of Antiquaries; and D.C.L. of the University of Oxford, LL.D. of Cambridge, Edinburgh, and Dublin, besides various foreign titles.

His parliamentary career has been one of practical usefulness. It began in 1870 with his election for Maidstone, after being an unsuccessful candidate for West Kent in 1865 and in 1868; in the latter year he was also nominated for London University, but retired in favor of Mr. Lowe. From 1870 to 1880 Sir John Lubbock sat for Maidstone, being re-elected in a stiff contest in 1874; but since June, 1880, he has represented the University, his supporters in that election comprising the most eminent living men of science in England; he had previously been vice-chancellor of the University for six years. He has always been a consistent Liberal, and is now a decided Liberal Unionist. Six or seven legislative measures, not of a party character, have been introduced and carried by Sir John Lubbock; the celebrated Bank Holiday Act; the acts for the amendment of the Constitution of the Apothecaries' Company, and of the Royal College of Surgeons; the Bankers' Book Evidence Act; an act to amend the law relating to falsification of accounts; the Absconding Debtors' Act; an act concerning medical examinations and degrees of the University of London; and the act for the preservation of ancient monuments. He has also been a member of the Public Schools Commission, of the International Coinage Commission, and of the Commission of Inquiry on the Advancement of Science, a trustee of the British Museum, one of the Senate of the London University, and active in other public work. As a leading member of the London Bankers' Association, of which he was honorary secretary, Sir John Lubbock has rendered many services to the conduct of their business, especially in extending the operations of the Clearing House, for the exchange of checks and daily mutual adjustment of payments between the banks, to the country banks as well as those in London; he has also promoted a scheme of examination, conducted by the City of London College, for bankers' clerks and those of joint stock companies. He is a magistrate for the county of Kent.

The portrait of Sir John Lubbock is from a photograph by Messrs. Elliott & Fry, Baker Street.—*Illustrated London News.*

RECENT EXCAVATIONS IN ANCIENT ROME.

By Sir JOHN LUBBOCK, Bart., M.P., D.C.L., LL.D.

SIR: During the last ten years few great cities have been altered more than Rome. Since it became once more the capital of United Italy, the population, and consequently the demand for house room, has greatly increased. On all sides I had heard lamentations that Rome was no longer what it had been. In one sense this is doubtless true. As a place of residence Rome may have suffered. Moreover, many of the pleasant gardens just outside the walls have been built over, and suburbs now intervene between the city and the Campagna. But these constructions and reconstructions necessarily uncovered many archæological treasures. Besides this, extensive excavations have been carried on in the Forum and elsewhere.

I knew, also, that my friend, Professor Pigorini, had been adding to the treasures of the Museum Kircherianum, and that under the care of Dr. Bernabei, an interesting collection of archæological objects had been brought together from the environs of Rome.

Under these circumstances I gladly seized an opportunity of paying a short, too short, visit to my Italian friends.

The recent additions made by Professor Pigorini, and the collections from Falerii brought together by Dr. Bernabei, which will, it is to be hoped, soon be opened to the public, are very interesting and important; but space compels me for the moment to confine myself to the results of the excavations carried on within Rome itself.

So far as archæology is concerned, these excavations have been under the superintendence of Comm. Lanciani. The number and variety of the objects discovered and now collected in a temporary building near the Arch of Constantine will be shown by the following, which M. Lanciani has given me. The objects discovered comprise no fewer than 705 amphoræ with inscriptions; 2,360 terra cotta lamps; 1,824 inscriptions engraved on marble or stone; 77 columns of marble; 313 pieces of columns; 157 marble capitals; 118 bases; 590 works of art in terra cotta; 405 works of art in bronze; 711 gems, intaglios, and cameos; 18 marble sarcophagi; 152 bass-reliefs; 192 marble statues, in a good state of preservation; 21 marble figures of animals; 266 busts and heads; 54 pictures in polychrome mosaic; 47 objects of gold; 39 of silver; 36,679 coins of gold, silver, and bronze; and an almost incredible amount of smaller relics in terra cotta, bone, glass, enamel, lead, ivory, iron, copper, and stucco.

This, moreover, does not include the objects discovered by the government in the official excavations in the Forum, Palace of the Cæsars, etc., nor those by private individuals.

Archæologists owe a deep debt of gratitude, which I gladly seize this opportunity of expressing, to the municipality of the city of Rome for the care they have taken in preserving the interesting antiquities of their great city.

"It is impossible," said Comm. Lanciani in a recent lecture, "for me to mention one by one all the discoveries made under the auspices of the city of Rome. We have discovered a new archæological stratum, totally unknown before—the stratum of prehistoric or traditional antiquities; we have discovered a necropolis older than the walls of Servius Tullius, containing more than 5,000 archaic specimens in bronze, amber, stone, and clay; we have brought to light more than 5,000 feet of the great agger or embankment of Servius, and ascertained the site of fourteen gates; we have unearthed the remains of numberless houses and palaces, temples and shrines, roads and drains, and parks and gardens, fora and porticoes, fountains and aqueducts, tombs and mausolea, to such an extent that whereas before 1872 science possessed only approximate attempts at an archæological map of Rome, we have put at the disposal of students magnificent ones, covering an area of 3,967,200 square meters of the ancient city."

Many of the objects discovered are of great beauty and interest, but how important it is to preserve even mere fragments is proved by the remarkable fact that the great masterpiece of Græco-Roman art known as the Farnese Hercules, now in the Museo Nazionale in Naples, was discovered in several pieces, the torso being discovered in the baths of Caracalla, the head at the bottom of a well in Trastevere, and the legs in the farm of "Le Frattocchie," ten miles from Rome!

Such extensive acquisitions and researches necessarily throw much light on many hitherto obscure points, and modify many previous conclusions; some indeed which it is impossible to abandon without regret, as, for instance, that with reference to the lovely little circular temple near the church of S. M. in Cosmedin, which is now said not to be the, even though we may cling to the idea that it was a, temple of Vesta.

Here, however, we cannot go into details, and I must confine myself to the main results.

Some archæologists have maintained that even before the time of Romulus, an Etruscan city "of great size and importance" had existed on the Seven Hills.

Mr. Middleton, indeed, in his interesting work "Ancient Rome in 1885," says that "the site of Rome was populous at a very remote and quite prehistoric period. Flint implements, and other remains of the early bronze age, have been found on the Aventine and in other places; and, especially on the Esquiline, tombs have been brought to light of the most primitive construction, dating probably from a much more remote period than the time traditionally given, 753 B.C., as that of the founding of Rome.

Nothing, however, has been found in the recent excavations which supports this theory. As regards stone objects, two only have been discovered, a flint arrow head, which had probably been kept as an amulet, and was discovered in 1874 near the church of St. Martino al Monti, together with bronze tools; while the second—an ax of jadeite—was found buried at a depth of 38 feet under the Monte della Giustizia, near the central railway station, but, as M. Lanciani points out, "it had no scientific value, as it was lying on the mosaic pavement of a Roman house built in the year 123 of the Christian era."

Comm. Lanciani considers that the recent discoveries have completely disproved the theory of a pre-Roman city. He, however, himself refers the foundation of Rome to the Bronze Age. I naturally differ with the greatest hesitation from M. Lanciani on any question connected with Italian archæology, but I cannot concur with him in this view.

Objects characteristic of the true Bronze Age are as rare as those of stone. None of the peculiar bronze knives or daggers, not a single bronze sword, has been discovered in Rome! On the other hand, fragments of iron have been found in an ancient tomb under the very agger of Servius Tullius. On the whole, recent excavations in Rome and elsewhere seem to disprove the existence of any more archaic city in times anterior to that of Romulus; they show that even at this early period the neighboring Etruscan cities had reached a high state of civilization; and they indicate that the foundation of Rome was posterior to the Bronze Age, and must be referred to the earlier part of the Age of Iron.—*London Graphic.*

THE SUBMERGED CITY OF CETOBRIGA IN PORTUGAL.

By NICOLAS PIKE.

OF all the nations of Europe, the small domain of Portugal, from the earliest ages of the world's history, attracted more than any other the attention of the various peoples on the seaboard of the "Great Sea," or Mediterranean. Phenicians, Greeks, Carthaginians, Romans, and, in later times, Spaniards and French have contested for its fair provinces and deluged it with blood. There is scarcely a doubt that the cities on the south and west coasts were founded by the Phenicians. Those bold navigators are supposed to have been the first to dare the horrors of the vast unknown ocean beyond the "Pillars of Hercules" on their voyages to the Cassiterides or Tin Islands off the coast of Cornwall, southwest of Britain, though history does not tell us how they first knew of these islands.

It is well known that early voyagers sailed pretty close to the shores in their small boats, and were always on the lookout for sheltering harbors, and founded colonies wherever they discovered wood and water. After settling Cadiz, on the south of Spain, as they passed along the coast of Portugal, so enterprising and commercial a nation as the Phenicians were not likely to overlook its rich and fertile soil, fine harbors, and abundant mineral treasures. All the early conquerors who settled in Portugal enriched the country with temples, triumphant arches, theaters, monuments to great men, and other fine buildings. It appears to have been the aim of more modern barbarians in their ignorance to destroy the works of their predecessors. They have done their best, not only to efface inscriptions that could tell of their founders, but where possible to wipe them out of existence. Many, however, were so solidly built that even their ruins are sufficient to show that those men of bygone ages were far advanced in the arts, and that their architecture in many details might be advantageously copied by modern workmen.

During my residence in Portugal I made it a point of visiting every place of interest I could, and through the politeness and kindness of the accomplished and interesting people, from the then king, Don Fernando, down to the peasants, every facility was afforded me to further my object. I had heard so much of the ruins of Cetobriga, I was determined to visit them if possible, but I had to gain permission from the government, as there was a decree that no one should go there without special order. I applied for a permit, which was at once granted, and I was also allowed to excavate to my heart's content, but on condition that all relics of interest I found should be given up to the Archæological Society of Lisbon. This I consented to do, and at once made preparations to go to the city whose past is enshrouded in mystery.

I had frequent occasion to visit Lisbon, and it was from this place I set off on my exploring expedition. The beautiful river Tagus is several miles wide here, and I had to cross it to commence my journey to Setubal, near the ruins of Cetobriga. This was made on horseback with a friend, and a most enjoyable one it was. We passed through a pine forest and then came to the town of Palmella, and passed the castle of the same name, situated on the brow of a steep mountain, nearly a thousand feet high, built in the 11th century. Then through orange groves and olive plantations. Fig trees and grapevines were everywhere, and flowers in abundance. A beautiful variety of heath, the deep red of the cistus, and many other plants embellished the earth.

We reached Setubal, or, as it is often called, St. Ubes, one of the oldest cities in Portugal, and whose foundation is attributed to Tubal, 2170 B.C. Notwithstanding its alleged antiquity, it is to-day the second city in the kingdom, with 20,000 inhabitants, and its public buildings vie with, if they do not excel, those of Lisbon.

Setubal was to be the base of our operations, as the ruins of Cetobriga, or Troya, as the Portuguese of to-day call it, lie about three miles across the bay. As we remained there for a day, we, of course, gleaned all the information of the lost city possible. It is said to have been built by the Romans on the site of a town founded by the Phenicians. This is conjectured from various coins and other relics having been dug up known to have belonged to that nation. It was only by accident that the city was discovered, and not till the beginning of this century. A fisherman pursuing his avocation along the coast was astonished to see walls of houses partially standing and well paved streets under the water of the Bay of Sines, and he

soon communicated the wonderful news to the inhabitants of Setubal.

On examination they found a city in part submerged and running in toward the land. The news spread rapidly, and very soon an archæological society was formed under the protection of government, with the king at its head, to make investigations. They found that the city had stood on a strip of land nine miles long by three broad, bounded on the south by the Bay of Sines, on the north by the River Sado, and opposite was Setubal. Every old record was searched, and at length it was surmised that the newly discovered city must have been Cætobrix or Cetobriga, from chance notices by old writers, but nothing was known of its history or fate. Excavations were begun and several streets were opened. Curious coins, armlets, bracelets, hair pins, and beautiful specimens of pottery were dug out. A ruined temple to Jupiter Ammon was laid bare, the portals showing symbols of the divinity, and from within was taken a statue without a head, bearing Roman inscriptions on its base, of remarkable beauty and workmanship. Among other discoveries was a goblet made of silver with mythological figures on its side, in red gold in relief, an exquisite work of art.

In the winter of 1814 a box was found that had been buried on the bank of the river Sado which contained tablets of metal, with curious and ancient texts on them. They were taken to the then Governor of Setubal, and a learned scholar was deputed to examine them in regard to their antiquity.

After careful investigation he decided they were of undoubted Phenician origin. A fine temple, with columns and capitals, and sepulchers containing human bones, was unearthed. Many vases were found still holding the ashes of incinerated bodies. Other sepulchers made of brick were opened, and some very beautiful ones of a vermilion red stone. Quantities of nails and bolts of bronze, with copper coins resembling a moedore, were found.

There is no doubt that the Romans possessed the city long before its destruction, as at every step their remains are encountered. Indications of Roman luxury show on all sides, and it is probable that many of the opulent class of that nation settled here to enjoy their wealth in peace and safety, in that delightful climate, and perhaps also to escape from the turbulence of Rome itself. The grand lifelike statues, the elegant and symmetrical columns of the public buildings and temples, the medals, sepulchral lamps and amphoræ, with so many other things prove a high state of civilization in the people who constructed them. One medal was found bearing the partly effaced inscription "Rex amenis datus," and six others of "Lucio Vero." A tablet was taken out near them bearing a singular writing in monosyllables of "admiration for the people of the city on the Tiber who created kingdoms, yet dethroned kings." Agostinho de Santa Maria gave a brief account, in which he says: "The site of this once populous and ancient city of Cetobriga, now in ruins, with its once grand edifices, numerous statues, and elegant columns, with their inscriptions, and other things of great antiquity, stands as an eternal monument of a people of whom we know nothing."

Having gained all the information we could at Setubal, we left for the ruins, and the officer of customs carried us and our attendants across the bay in the government boat. On landing we at once set to work exploring what had been already excavated. The floors of many houses we entered were exquisitely laid in mosaic, and most that we saw on removing the sand were as fresh and bright as when laid untold ages ago. In what was supposed to have been the kitchen of a house a small earthen frying pan was dug up, and in it was found substance concluded to have been meat. One small room we examined had evidently been a bath, about 8 ft. square. The structure was so admirably executed that I exclaimed to my companion, "Such work cannot be excelled in the present day."

The floor was bright and perfect, and resembled a richly painted oilcloth. Nearly every house had its bath room, and the mode of heating and conveying the water to the pipes was ingenious. At the back of the house was built a large permanent square tank made of broken shells and pottery, cemented together and fire proof. The fire was built under the tank, and the hot water conveyed to the bath through the flat earthen pipes.

The streets had all through them pipes for fresh water to supply the city, and fountains had been numerous. Every place we investigated showed the strongest indications that the inhabitants had been a wealthy, prosperous people. As so many objects of copper, bronze, gold, silver, and lead were found, it is pretty certain that they knew of and worked the mines not far from the city. They still exist, but in consequence of the absurd restriction on their working, they are of comparatively little use in the present day, whereas the mineral treasures of Portugal here and elsewhere under liberal management might be a source of great wealth to the country.

I particularly noticed a block of granite that had formed part of a corner wall of a house. At some time it had been broken and then neatly mended by a piece being inserted, and the cement used was the color of the stone, and only by close observation the break could be traced. I tried to remove the piece, but the stone broke before the cement gave way, and such a one would be invaluable now. I gazed with wonder and amazement on these evidences of long past civilization.

Near the water stood a number of tanks four or five feet square and as many high, and their walls several inches thick. They were composed of broken earthenware and shells cemented together, and they formed a concrete as hard as flint. It was difficult to surmise the use of these curious tanks, but it was conjectured that they served the fishermen to pack their fish in when salted. The plaster and cement used in all their buildings was of a superior quality. So were their bricks. Something was mixed with the clay to render them tough and durable.

I made an attempt to do some excavating on my own account. Our men set to digging, but the sand worked back so fast it was a very difficult task. After considerable hard work I was rewarded by finding a copper coin, a mining instrument such as was used by the early Romans, and an earthen *lampada* or small lamp. We came on a heap of broken crockery, some of it showing marks of elegant designs when perfect, and among it some small amphoræ of a quality I have rarely seen equaled.

Numbers of lampadas have been found, many of them of unmistakable Eastern origin. They were of various materials, such as stone, glass, earthenware, iron, bronze, large shells, and even gold and silver, of different and curious designs. They had lampadas for public and domestic use, but those serving for sacred purposes and sepulchers were of distinct forms and substances.

The city extended quite a distance along the promontory, but a large portion of it was submerged under the sea. As I rested from my labors and contemplated these singular ruins, my mind went back to the time when the inhabitants of what must have been a populous city, bent on commerce or pleasure, affluent and cultivated, displayed the same human passions as those of our own day. What had so utterly swept it out of existence? No record left to tell the tale for countless centuries. I thought of Pompeii and Herculaneum, whose fearful ending was comparatively recent and recorded, and yet they were utterly forgotten till accident revealed their whereabouts. Surely some similar terrible fate had overtaken Cetobriga. The sea had evidently combined with some terrible earthquake far worse even than the one of 1755, and at one fell swoop it and its populace were overwhelmed in ruin, perhaps swallowed up instantaneously, as were many parts of Lisbon later, the sea taking a large share of the spoils. It was hard to realize how the waters of that now bright calm bay could have reared their waves so high as to engulf those grand temples and monuments.

There seems no means of finding out either its origin or the terrible catastrophe that swept it from the surface of the earth.

FIG. 1.—A PERUVIAN SILVADOR.

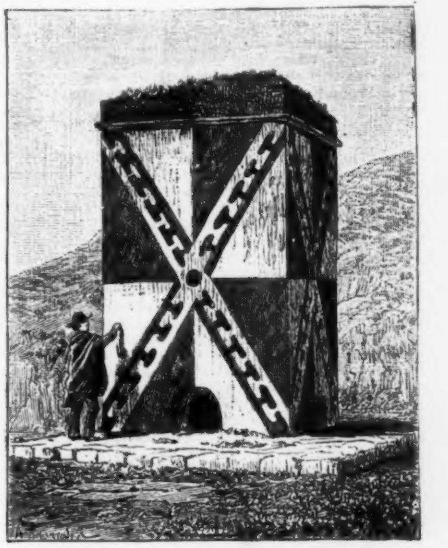


FIG. 2.—A BOLIVIAN CHULPA.

THE POTTERY AT THE CARACAS MUSEUM.

AMERICA is the classic home of pottery, the debris of which are met with in large quantity in all the regions that are washed by the Atlantic and Pacific. They are found beneath mounds—those great tumuli due to unknown builders—amid the aerial dwellings upon the often inaccessible rocks of Arizona and New Mexico, on the islands at the mouth of the Rio de la Plata, in the old burial grounds of California, in the huacas of Peru, etc.

These wares everywhere exhibit a curious resemblance; and a certain originality of form testifies to an indigenous art that offers no affinity with the art of our ancient continents.

For some years past, the Americans have understood the importance of these old witnesses of past ages. Collections from all quarters have been formed, and museums have been opened in which are stored with jealous care all the relics of the past. Of these, the one at Caracas, under charge of Dr. Ernst, is one of the most flourishing, and we think that we shall interest our readers if we give a few details concerning the little known pottery with which this museum has just been enriched.

First, let us cite a *silvador* (Fig. 1), one of those double vessels peculiar to Spanish America, which, when filled with water, emit a more or less prolonged whistling sound produced by the escape of air. This silvador was found in a burial place near Ayacucho, and it is thought that the ancient Peruvians made use of similar vessels in their religious or funeral ceremonies. This form has been known for a long time, and the Museum of the Trocadero contains numerous and interesting examples of it, but the one which we reproduce merits attention by reason of the woman's face that surmounts it. The headgear is odd, and it perhaps recalls that which was formerly worn by the women of the country. The forehead exhibits that artificial deformity so frequent at the north as well as at the south of the American continent.

At the time of the Spanish conquest, most of the aborigines, especially those who lived on the Pacific coast, had preserved their old habit of compressing the heads of infants at birth. The most recent of such deformities, that reproduced in our pottery, has been the artificial flattening of the forehead. This process caused the head to enlarge at the sides, and, by a curious coincidence, we find this same mutilation practiced in our day in the Caucasus.

It was not the only one admitted by fashion in America. At the congress held at Nancy in 1875, there was exhibited an Aymara skull found in Bolivia, which came to a point, another from the same country that formed a true cylinder, an Indian skull flattened from front to rear so as to give the frontal region enormous dimensions, and, finally, a Patagonian skull which had undergone such a pressure that it offered a bicornous appearance.

The second piece of pottery that we desire to call attention to came from a *chulpa* of Bolivia. The chulpas are towers, sometimes round, sometimes square, formed of a mass of undressed stones and clay, and covered externally with great blocks of trachyte or basalt, and then with white and red stucco, so arranged as to form varied designs. In the center there was a cist in which the bones were deposited after having been previously scraped. The narrow aperture that gave access to it scarcely exceeded eighteen square inches (Fig. 2).

These chulpas are numerous in Bolivia and throughout Callao. They may be seen in groups of from twenty to a hundred upon the sides of the mountains and upon isolated rocks. They everywhere form one of the characteristic features of the landscape. All, and particularly the one that we reproduce, contrast singularly, by the carefulness and elegance of their construction, with the rude pottery that these tombs conceal.

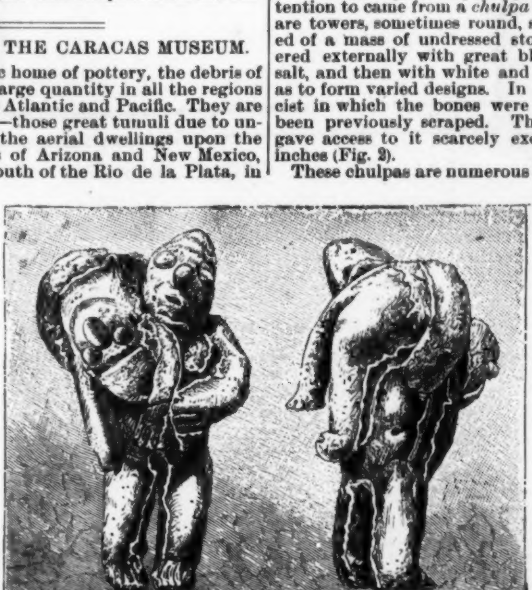


FIG. 3.—BOLIVIAN POTTERY.

The pottery that we reproduce is very crude (Fig. 3), but the excavations up to the present have given nothing that could be compared to it. An Indian is carrying a corpse upon his shoulder. Is it a sacrificer carrying the victim that he has just offered to his gods, insatiable of human blood? We are unable to say, and the tomb has guarded its secret. The bodies are naked and the heads covered with the little conical cap that the inhabitants of the Cordillera of the Andes still wear.—*La Nature.*

[FROM ENGINEERING.]

PORCELAIN MANUFACTURE IN FRANCE.

THE recent exhibition in Paris afforded ample evidence of the enormous progress that has been made in France in the ceramic art, as, indeed, of almost every other industry.

A volume could, and ought to be, written on the raw material, the methods of its preparation, the means employed for giving it form, the art introduced in its decoration, and the appliances for subjecting it to the heat necessary for its completion.

From time almost immemorial, Limoges and its vicinity have been famous for porcelain, and this reputation, due, of course, in a large degree to the excellence of the clay, has not diminished; on the contrary, it is to-day one of the great centers of France of this great industry.

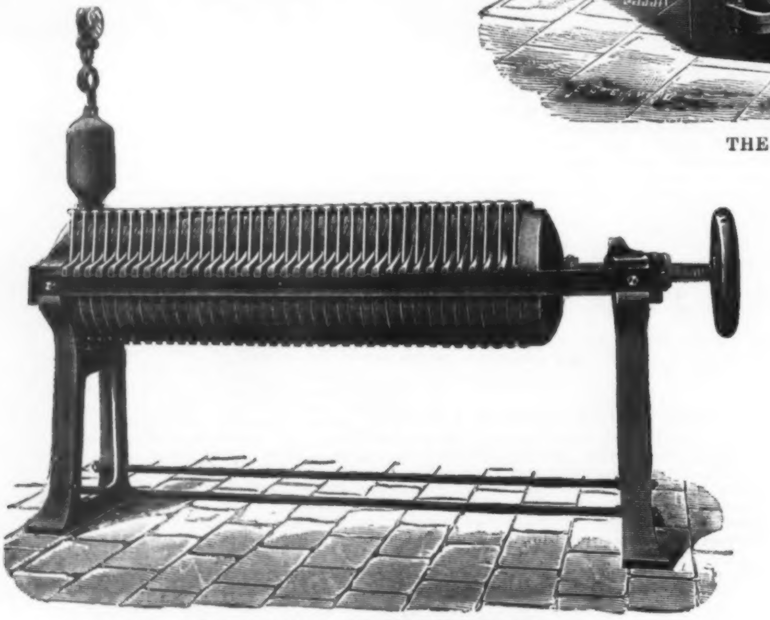
Competition and natural progress have of late brought mechanical appliances into use, that for the commoner and most generally used domestic utensils have displaced the old potter's wheel, and have given to the manufacturer machinery by which production is at the same time increased, improved, and cheapened.

The principal worker in this field is M. P. Faure, of Limoges, who showed at Paris a large and very complete collection of this class of machinery, which we propose to illustrate, commencing with the appliances used for the first preparation of the clay, before it is placed in the edge running mills, and reduced to the proper condition of plasticity required for subsequent treatment.

The clay, after being excavated, and roughly separated from stones and other impurities, is placed in a tank and mixed with water until it has about the consistency of cream; continued agitation with stirrers makes the mixture as complete as possible, and after a certain delay for settlement, communication is opened between the tank and a suction and force pump, which delivers the liquid into the filter press.

The mixed clay and water are not allowed to come in contact with the plunger of the pump, an elastic diaphragm being interposed, the vibrating movement of which forces the material into the press; the pump cylinder has two plungers, one working within the other, and so arranged that the smaller one can be put in operation when it is desired to increase the pressure in the filter press.

THE PORCELAIN PUMP.



THE PORCELAIN FILTER PRESS.

The last-named apparatus has a cast iron frame, on the longitudinal bars of which are hung a series of cast iron rings covered with iron gauze; between the frames thus formed canvas bags are placed, so arranged that the liquid which is delivered by the pump to a central opening in one end of the press receives it, and allows the water to pass freely.

The series of frames and bags are held together by the end screw, and the pressure that can be exerted within the filter by the pump varies from 120 lb. to 150 lb. per square inch; the clay freed from the water that held it remains in the form of compressed cakes in the bags, and about 500 lb. of clay ready for the edge runners can be turned out from one of these presses per hour.

After having been removed from the compartments of the press, the clay is heaped upon the table of the edge roller mill, which we represent. It consists of a table from which rise two standards connected near the top by a cross beam, that serves as a bearing for a central vertical shaft supported at the bottom and in the center of the table by a footstep; this shaft is driven by a pinion on the pulley shaft that gears into a large bevel wheel on the vertical spindle. Near the bottom, this spindle is enlarged to receive the horizontal shafts of two coned and grooved rollers, mounted so that their tapering peripheries lie in similar planes, and below these shafts are two others at right angles to them to which are hung vertical tapering guide rollers, the distance between which can be adjusted by altering the positions of the bearings on the shaft. The table is formed with a coned surface parallel to one of the grooved tapering edge runners.

The clay, being placed on the table, is pressed outward by one of the runners and inward by the other, while the hanging guide rollers define the position it must take upon the table.

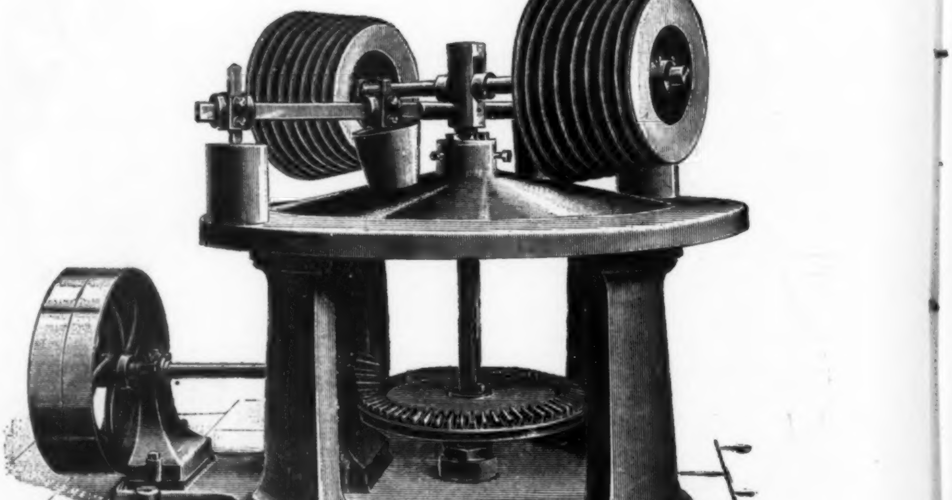
As the mill is driven, the clay upon it is worked up thoroughly by these various rollers until it has become thoroughly homogeneous.

The machine illustrated requires 4 or 5 horse power to drive it, and can turn out from ten to fifteen tons per day.

We give an engraving of a smaller and somewhat similar machine, in which the clay receives a final working before it is moulded. In this case the driving gear is placed under the table, the coned and grooved edge rollers are smaller, and their shaft is mounted in a slot in the vertical spindle, so that it can rise under any unusual resistance.

The clay is only worked in this machine for about twenty minutes, in smaller quantities, but at a higher speed; it requires about 1½ horse power to drive it, and finishes about three tons of clay per day.

When the material is thoroughly manipulated, it is taken from this machine and cut up into pieces, each of the size required for the finished object. This is then placed in a machine which spreads it into a disk, and which we shall refer to on another occasion. The disk of clay is placed on the moulding machine shown; this machine carries on a vertical spindle, driven by a small pulley, a socket in which is placed the mould, in plaster of Paris, of the object to be made; the disk of clay being laid on this mould, the latter is caused to revolve, and a pressure plate is brought down on the

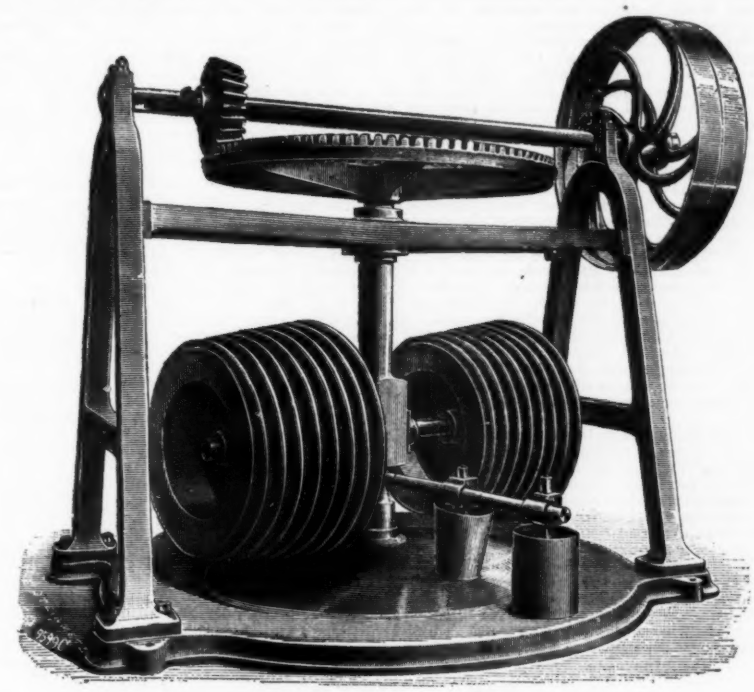


SMALL EDGE ROLLER MILL.

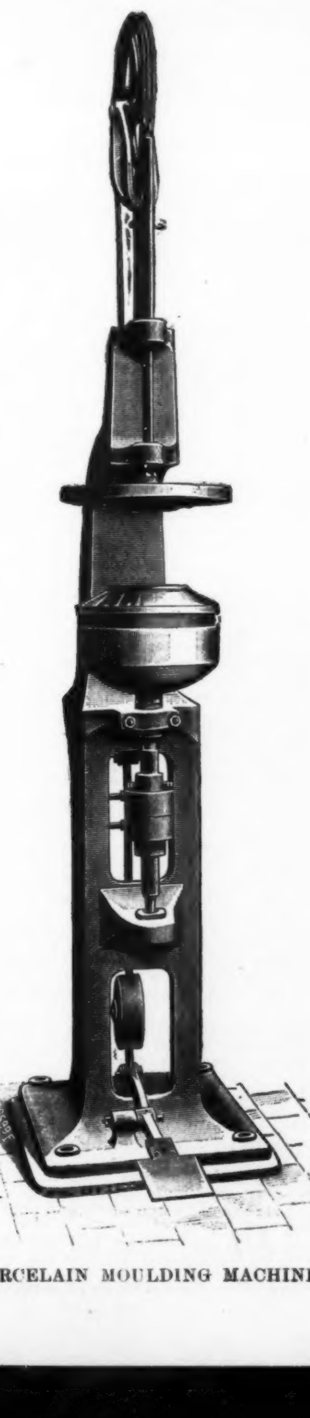
clay, forming the back, and forcing the clay upon the mould; after this is done the mould is shifted on to the finishing machine.

The principal feature of this machine is the fixed template, varying with the form of the object to be made. A variety of movements are introduced for raising or lowering the template holder; as the mould is revolved the clay is pressed against the edge of the template, which forces off the superfluous parts, and the vessel is completed. A set of these machines can turn out fifty dozen of plates a day.

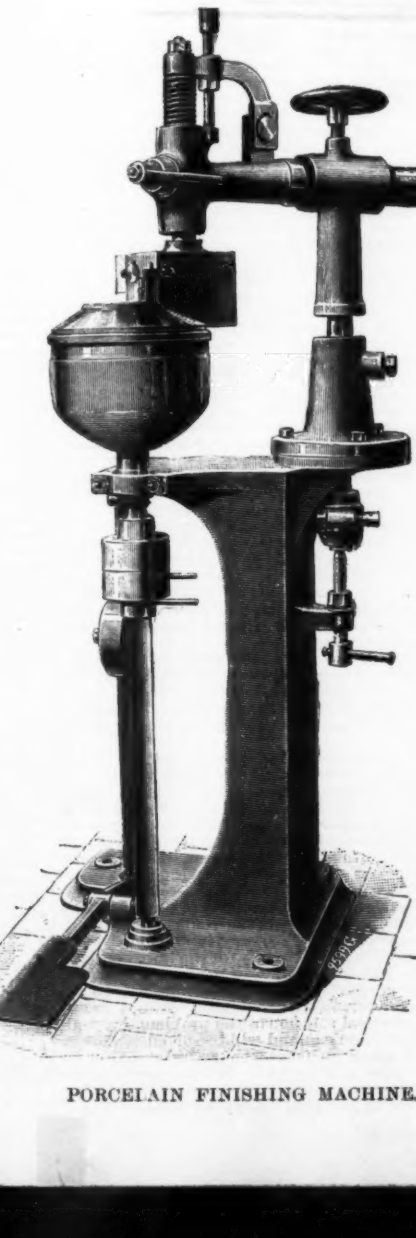
(*To be continued.*)



EDGE ROLLER MILL FOR PORCELAIN CLAY.



PORCELAIN MOULDING MACHINE.



PORCELAIN FINISHING MACHINE.

THE TENSILE STRENGTH OF SHEET ZINC.

So little has been published about the strength of zinc that any contribution to this question must be welcome. The most careful tests which Professor Martens made on some zinc sheets supplied by the "Schlesische Actien-Gesellschaft fur Bergbau und Zinchuttenbetrieb" at Lipine, in Silesia, on behalf of these works, hence deserve all the more attention. These tests were carried out at the Royal Technical testing station at Berlin, of the mechanical department of which Professor Martens is chief, and are described in the official reports of this institution, 1889, IV. We are indebted to Professor Martens for a copy of his descriptive pamphlet, a little book of thirty-two pages, with two plates, comprising more than ten pages of tabular matter. The interest attached to these tests is less of a directly practical than of a scientific nature, and the report will be appreciated especially in engineering laboratories and by those interested in testing work and its machinery. Such apparatus are generally far too complicated to permit of a condensed description; and as those devised by Mr. Martens are moreover still undergoing improvements, and concern more the reliability of the indicating mechanisms than the actual zinc tests, we must confine ourselves to a few remarks.

The reputation of zinc as a structural material is not particularly good, and these tests do not tend to show that the metal deserves a better name for constancy and reliability of its mechanical properties. A great many tests had to be made to arrive at fair averages. The test samples were five sheets, supplied by the Silesia mills of the above works, two specimens from foreign works, and finally eleven sheets rolled before Professor Martens out of bar plates of 1 foot width. Three of these latter were rolled out to two, three, and four times their length, to thicknesses of 6·1 mm., 5·4 mm., and 3·1 mm.; the other eight were rolled in bundles, first in one direction, then at right angles to this direction, test pieces being cut out each time when the length had increased by 500 mm.; the final plate varied in length from 1,210 mm. to 4,710 mm. and in thickness from 1·1 mm. to 0 6 mm. The chemical analyses of the various plates agreed very closely; they all contained about 1 per cent. of lead and 0·02 per cent. of iron, the two foreign plates showed traces of antimony; no other metals were observed.

The first series of tests was made with a horizontal Rudeloff testing machine, with scale pan, screw, and nut feed, the prismatic test pieces of 20 mm. (0·8 in.) in width being fixed in caps and tightened there by means of wedges. The pieces frequently broke close to this clamp, and it was found that the length of the wedge and the distribution of the pressure was of considerable importance; the wedges should press out the mouth of the clamp slightly, but more and more toward the back. Direct application of the loads proved quite unsuited, as zinc is highly influenced by the rapidity of the changes. Professor Martens, therefore, resorted to a testing machine of his own design, three different modifications of which were employed. As indicators for these apparatus a circular vessel filled with mercury was employed, from the side of which a vertical tube branched off; the cover of this vessel was formed by a strong central plate supporting a weight surrounded by a ring of German silver. The strain imparted to the test piece was partly taken up by the weight, the mercury column effecting the balance.

This arrangement, which resembles others employed for similar purposes, did not answer; it was, moreover, not self-recording. The mercury tube was therefore replaced by a horizontal cylinder with a piston rod ended in another piston moving in a second cylinder with a slide valve, which was actuated by an electric device comprising electro-magnets and relays; the common piston rod carried a pointer recording on a paper drum. A third device, also electrical, but worked by gravity instead of water pressure, was employed for the highest loads up to 50,000 kilogrammes. These three arrangements labored under the disadvantage that the cover of the mercury vessel retained an amount of mobility suffcient to affect the accuracy of exact measurements. Professor Martens hence returned to an often employed arrangement, utilizing the elasticity of a spring of an elastic steel rod; and the pamphlet deals exhaustively with the preliminary tests of steel rods and of the new automatic recorder with which it was combined. This latter invention, probably the most interesting part of the paper, would require a detailed and illustrated description. The idea is that the variations of the rod are marked directly—and without being magnified by multiplying levers or other devices whose accuracy Mr. Martens altogether questions—by means of a little conical diamond point on glass plates of the size for microscopic slides, fixed on a platform moved by means of a micrometer screw and adjusting spring, in a direction at right angles to that of the axis of the rod. Two of the resulting curves would occupy a space of not more than a square millimeter; the plates were examined and measured in a large Zeiss microscope provided with micrometers for both object and ocular glasses. In this form the recording device has been constructed by Mr. Boehme; it is, however, intended to leave the platform at rest and to register the movements in the direction of both the abscissæ and the ordinate.

The chief objects of the tests were to ascertain the elasticities at ordinary temperatures and at 80 degrees, 120 deg., 150 deg., 170 deg., and 200 deg. Cent. (between 176 deg. and 392 deg. Fahr.), and to ascertain the influences of different modes of rolling and of time effects. The latter are striking. One can hardly speak of the elasticity of rolled zinc, as even under very small strains the permanent expansion varies with each change of load; there was always a noticeable after-stretching.

When cold the breaking strength was 23 per cent. larger, the breaking extension 22 per cent. smaller, and the "fullness degree" (*i. e.*, the ratio of the area comprised by the curve to the rectangle formed the greatest extension multiplied by the greatest force) about the same in a direction at right angles to the rolling than in the direction of the rolling. The two samples supplied by other works showed, however, opposite characteristics, and one test piece particularly deviated in a manner probably to be accounted for by some peculiar treatment during manufacture, the

chemical composition seeming to afford no explanation.

Rising temperatures modified the results. The breaking strength increased considerably in thinner sheets—that is, in such as have undergone greater and more continued pressure in the rolls; it rose from 11 kg. per square millimeter for 6 mm. plates to 19 kg. for plates 0·48 mm. thick. The English equivalents of these values are 17·5 and 30 tons per square inch respectively for plates of 0·24 in. and 0·019 in. thickness. The breaking extension decreases first and increases rapidly afterward.

For the temperature tests, the pieces were heated in a linseed oil bath; the results confirm the well known and important fact, first established by Sylvester and Hobson, of Sheffield, that zinc should be worked, rolled, stamped, turned, etc., at 300 deg. Fahr., and that any higher temperature should carefully be avoided. On the whole the tests demonstrate clearly that ordinary tensile strength tests are not alone sufficient, and should be combined with folding and bending tests.—*Engineering.*

STEEL ALLOYS.

Mr. James Riley, the general manager of the Steel Company of Scotland, has again dealt with the subject of alloys of steel with other metals, this time, says *Engineering*, in a lecture to the Greenock Philosophical Society, "in honor of the anniversary of the birth of James Watt." This society has annually such a lecture, usually by one who by his work has merited a place among leading scientists; and in inviting Mr. Riley to read a paper they paid a compliment as deserved as it was graceful. With the view of associating the subject with the great work of Watt, he referred to the connection between the steel maker and the engineer.

The former required the power of the steam engine to contend with, to make use of, and to control many of the most powerful forces of nature, and the steel maker's work rendered possible those marvelous developments in engineering which are the special features of the past dozen years. It is not advisable here to follow Mr. Riley in his very carefully prepared exposition of the "manufacture, properties, and uses" of steel; but as he was clear in his expressions of opinion on one or two matters of paramount interest at the present time, it may be interesting to refer briefly to these.

Since the production of his paper on "Alloys of Nickel and Steel," at the Iron and Steel Institute, the pros and cons of several alloys have been discussed more freely than formerly. A great deal, for instance, has been said and written of the advantages to be derived from the use of aluminum in the manufacture of steel, but so far as Mr. Riley's experience goes—and it is of considerable extent—he thinks this usefulness is considerably overrated.

The use of aluminum in the molten steel, Mr. Riley says, greatly increases its fluidity and its melting point, and thus enables one to make castings which shall be sound, and which, being cast at a lower temperature, shall be less subject to the hot cracks due to contraction. But then equally good results can be and are obtained without its use, as he had demonstrated to more than one of its advocates. Further experience led him to the conclusion that the strength and ductility of steel are not improved by additions of aluminum, even if they are not slightly impaired.

Thus, then, as this metal is as yet a very costly one, although daily becoming less so, it is only in a tentative, careful manner that he would use it. We may incidentally note that it is stated that a factory for the making of aluminum by the electrolytic process as used in Neuhaus, Switzerland, is about to be formed in Austria. Hitherto it has been used most largely for opera glasses, and as a small ingredient in the manufacture of cast steel, by which the metal is made more tenacious.

The high price has hitherto hindered a more general use of the metal for industrial purposes; but as the system to be adopted will reduce the cost of production, it is probable that its price will result in its being used in many directions. The alloys of iron and manganese steel need not be dealt with here. Chromium, largely used as an alloy with steel, particularly for war purposes, was next referred to, and here Mr. Riley, although he did not mention it, was speaking with the authority of a producer of chrome steel, as his company have recently provided protective plates of this metal for a Japanese cruiser building in the Clydebank yard.

Chromium, like aluminum, he says, is somewhat expensive to use, its first cost being considerable, and the loss by oxidation great. Considerable care and skill are required in the production of chrome steel to get the necessary amount of chromium present together with a reasonable amount of carbon. The effects of chromium in steel are shown in increased hardness and strength and some loss in ductility, in increased facility for hardening and tempering in water or oil, and also in great difficulties in machining. In working this steel at the hammer or rolls, care must be taken that the masses of steel are heated very gradually and not to a very high temperature.

"The most important of the alloys, and the one which is likely to prove of greatest interest, because of its great utility," is ferro-nickel or nickel steel. No serious difficulties, he says, are met with in alloying it with iron or steel to any extent, no special plant required. Most remarkable properties are possessed by this steel, properties which vary to a very large extent, according to the contents of the nickel.

When present to the extent of not more than 7 per cent., the effects are a great augmentation of the hardness and tensile strength, a very considerable raising of the elastic limit, and much less corrodibility. As in the case of manganese steel, so in the region between 7 per cent. and say 20 per cent. of nickel, the alloy becomes exceedingly hard, somewhat brittle, and it is utterly impossible to machine it. Beyond this region its properties are again modified, very great ductility being found, together with high tensile strength, and practical incorrodibility.

Steel containing say not more than 5 per cent. of nickel has an elastic limit of about 28 tons, an ultimate tensile strength of over 40 tons, with an extension of over 15 per cent. on 8 in. This steel can be machined with moderate ease, and stands punching very well, both in its annealed and unannealed condition. As a demonstration of its great importance, he mentioned that with nickel steel the engineer had the means placed in his hands of nearly doubling boiler pressures without increasing weight or dimensions. It will be remembered that when the subject was being discussed at the Iron and Steel Institute, the question of the manufacturing cost of nickel was raised.

Then Mr. Riley said he had a vague notion, arrived at by some very casual calculations, that the cost of production would not be prohibitive. And at the more recent lecture he said that the probability of the introduction of nickel steel into industrial arts has developed considerable excitement among the owners of mining property where nickel is found, and he anticipated that in no long time the supplies of this metal would be so much increased that it will be possible to supply the steel at prices which will not be considered at all unreasonable. He made no intimation as to manufacture, but the Steel Company of Scotland, it may be taken, will be ready to supply nickel steel when called upon by any of their numerous clients.

Speaking of steel made by the basic process, Mr. Riley was very pronounced in his opinion. The basic process, he said, has been useful to the world in general, but as yet has been sadly disadvantageous to Great Britain. This, he thinks, is in part due to the distrust which has attended the use of basic steel in this country, a distrust which will not be easily removed from the basic Bessemer process, but for which there is no ground in connection with the open hearth basic process.

The whole operations in the basic Bessemer process are of such a character as to render it peculiarly easy to produce metal which shall not be thoroughly homogeneous and of a perfectly reliable character. He knew and frankly admitted that by the exercise of the greatest skill and care this can be avoided, and thoroughly good steel be produced; and evidence of the truth of this remark has been furnished in the steel sent out from works in the West of Scotland. Yet none the less did he assert that only in the open hearth furnace can the basic process be conducted with such uniformity, regularity, certainty, and comparative ease as will warrant that firm confidence in results which has been developed with regard to acid steel of high quality.

PRODUCTION OF LIGHT.

Within two years the wonderful experiments of Hertz have demonstrated beyond question that electromagnetic waves travel through space from every source of alternating currents or potentials, and that the waves travel with the velocity of light. In this city there are, I suppose, many alternating current systems. When we think of these in action, we are apt to think only of the activity in the conductors of the machines, the lines, the transformers, the lamps, and yet we know that in all the space around there is activity. Waves are chasing each other through this room, through our streets, our houses, our offices. They are everywhere present.

We are bathed in this agitated medium every moment, and yet we live, and not only live, but are totally unconscious of the activity that surrounds us. No sense responds to the wave motion that fills this space. And yet, when these waves become short enough and frequent enough, they do affect our sense of vision, and a vast array of phenomena that otherwise would have had no existence for us are made known to us through this special sense. But the eye only responds to waves of $\frac{1}{35000}$ to $\frac{1}{57000}$ of an inch in length, while the length of the waves emitted by one of our alternating current systems is 600 miles.

The waves that affect the eye must occur at the inconceivable rate of at least 400 millions of millions per second, while less than 300 waves per second are emitted from our alternating systems.

These waves come very far short of the number necessary to effect any of our senses; but we have been able to demonstrate their existence; at least we have been able to show that something possessing all the characteristics of wave motion exists in the space around a source of alternating currents or potentials. It is something to know that waves of such enormously different lengths and frequencies exist in the medium that is agitated by waves of light. It is something to understand that our sources of alternating currents are centers of radiant energy, differing from light only in wave length; and since we have begun to appreciate this fact, we have often asked ourselves the question: Can the rate of alternation be increased until the whole apparatus should glow with light?

Although the enormous rapidity required seems to render this direct solution impossible, it seems to me there must be a way to obtain the light we want without all this waste of energy. I cannot believe it will always be necessary to develop waves of all lengths, from many miles down to a hundred-thousandth of an inch, in order to obtain the narrow range of wave lengths by which we see.

I do not know of any practical way of obtaining the few wave lengths that constitute light without at the same time producing the others, but it *is* done.

The glow worms do it, the fireflies do it, the lantern beetles do it, and I believe the time is coming when man can do it.

Instead of getting ten 16 candle lamps per horse power, we ought to get 200. I don't know how it is to be done. I don't expect we are going to make alternating machines to produce 500 millions of millions of alternations per second. But possibly we may solve the problem indirectly by the use of some substance having a special rate of vibration, such as the gases. Possibly we may be able to excite electrically the fluorescent salts. Possibly we may be able to charge and discharge a condenser and take advantage of the oscillatory discharge to set up vibrations of the frequency required. Possibly we may discover the secret of the glow worm and firefly and substitute electric for the insect energy. I know it will take several fireflies to equal a 16 candle lamp, but it will also take a good many fireflies to develop a horse power. But although I do not see at present any practical solution of the problem, I repeat, I believe the problem can and will be solved.

We are not going on forever burning a coal mine whenever we want a little light. Neither are we going on forever converting the energy of coal into heat when it is mechanical or electrical energy we want.

From the very nature of things, not more than one-fourth or one-third the heat so produced can be transformed into any other form of energy. The energy of fuel *can* be converted into mechanical energy without first becoming heat. It *is* so converted in every animal movement. The way exists; let us find it.

Find this, and the way to make light only when it is only light we want, and we shall have lengthened the life of our coal deposits five or ten times.

The man who solves either one of these problems will be the greatest discoverer of this or any other age. If he gets a broad patent on it, he will have seventeen years of the grandest litigation the world ever saw.—*W. A. Anthony.*

[From the New York Tribune.]

THE NEW CROTON AQUEDUCT, NEW YORK.*

In the foregoing account of his journey through the new Croton aqueduct, the reporter got only as far as shaft No. 4, out of which he rode in a big iron bucket in company of Mr. Rice, deputy chief engineer, and Mr. Gowen, division engineer.

The next morning the tour was continued from the mouth of that shaft. Every-day clothes were exchanged for rubbers, as before, and, also as before, the tourists presented a rather frightful appearance, which, however, concerned them not, as they were not out for observation.

The bucket went down very sedately, descending upon the invert as softly as dew upon the mown grass. Mr. Gowen took the tin reflector, as on the first day, while Mr. Rice and the reporter took candles. There was a strong draught, and the warm, moist air of the tunnel, sweeping up the cold shaft in a great volume, so packed it with vapory clouds that the bright daylight was suddenly shut out, leaving the bottom of the well in semi-darkness. The shaft steamed at the top like the exhaust pipe of a great engine.

The tourists hastened their steps to get beyond the draught, which wet them and chilled them at the same time, and put enormous gutters in the candles, with a leaning from the windward side.

Mr. Rice had a trick of swinging his candle between the second and third fingers of his right hand and forming with the back of the same hand a shield to keep off the wind. It seemed so easy to do that the reporter tried it.

Result: One coat cuff demolished, one shirt cuff scorched, one palm blistered, and the tunnel filled with a refined odor of burnt rubber.

Added to this misery was an affection of the ankle bones and heels, due to the sidehill boots, but as a car horse warms out of his lameness, so the reporter warmed out of his, and at last locomotion became a melancholy pleasure on the slippery, sloping banks of the diverted Croton. A hatful of water poured into the bootleg at the end of every mile prevented spontaneous combustion.

THE OLDEST INHABITANT.

The tunnel was grotesquely dark for a quarter of an hour, the lights penetrating nowhere, the eyes seeing only their faint flickering. When this condition partly passed away, the nebulous cone reappeared. By and by a grinding, crunching sound was heard. It seemed to come from a spot some fifty feet distant, but after walking in its direction for half a mile the tourists still heard it in front of them. A dull red star appeared. To the reporter it looked a mile off. Mr. Rice thought it about 1,500 feet away, and Mr. Gowen guessed that it was 1,300. It proved to be just 700. The atmosphere was smoky and deceptive. The crunching sound and the star were found at the same spot. An Italian, wearing a miner's lamp in his hatband, was shoveling grout into a car. As the reporter approached the place, something black and big, like the ghost of the departed Jumbo, rose up before him, and he stopped to put out his brave right hand to feel his way.

There is nothing more desirable in subterranean corridors than a proper degree of caution. But for the extended right hand there would have been a collision between two unequally matched faces—the face of a reporter and the face of a mule. The result might have been disastrous to the mule.

The strangers beamed lovingly on each other. Both were probably from Georgia, and you know how friendly to one another strangers always feel when they meet in a strange land.

The mule's eyes, closely examined by candlelight, were lusterless. Their color was an indigo blue, the color of the nebulous cone that forever opened in advance of them. The candle blinded them, and there was a great winking and blinking. The animal's coat was shaggy, but he was fat and good natured, permitting himself to be handled from ear to hoof. The water was nearly up to his knees as he stood in the middle of the stream, and he seemed to enjoy paddling in it. The reporter picked up his feet and saw that he was well shod.

"How long has this fellow been down here?" the Italian was asked.

"Two year-a," he answered.

It was even so. That mule is the oldest inhabitant of the tunnel. For two years he has seen no daylight, except such faint rays as steal through a shaft to be swallowed by the black-throated hole.

Near shaft No. 6 the tourists came upon his stable, a wooden bench three feet wide and ten feet long, raised above the water line on the west side of the tunnel. At the north end there is a box containing the remnant of his breakfast, a wisp of hay and a quart of oats.

At evening, when his day's work is done, the mule shakes the Croton water off his hoofs and ascends to his little bunk, where he passes the night in solemn silence. As he cannot hear the chickens crow 400 feet above him, and is not provided with a clock, the question is, How does he tell the hour?

Verily, that oldest inhabitant's lot is not a desirable one, yet it has its advantages, and possibly its consolations.

It is not every mule that can sleep in a bunk in a tunnel; nor is it every mule that can hop out of his bunk into a stream of Croton water and paddle about in it all day.

This mule, when the reporter had the pleasure of meeting him, was hitched to a dump car, which was

* Continued from Supplement, No. 741, page 11835.

nearly as wide as the tunnel. The wheels, made of wood, had a tread of six inches, and were without tires, in order that they might do no damage to the pavement, for there was no track for them to roll on. Once upon a time they were round, but now it was noticed that they had worn themselves square. Each presented four sharp corners and four flat sides, a condition unusual with wheels of any description. How and why they should have given themselves this shape is one of the tunnel mysteries. No man on the work pretends to explain it.

HOW THE WORK WAS SCAMPED.

The tourists bade the mule farewell and continued their journey. The water deepened rapidly, overspreading the banks and climbing up the side walls. The current was stopped, the stream became a pond in which six big boots went splash, splash, splash. A temporary dam was reached and crossed, and below it the invert was once more comparatively dry.

It was north of this spot that discoveries were made which led to the exposure of the aqueduct frauds. It being impossible for a division engineer to superintend in person the work of construction going on in a dozen or more places at the same time, the commissioners appointed a large corps of inspectors, whose duty it was to remain with the work day and night, to see that it was done properly and according to the specifications. These inspectors—at one time there were 250 of them in the tunnel—were supposed to keep the engineers informed of the doings of the contractors, and if there was any shirking or scamping, to direct immediate attention it.

Some of them did their duty. Others leagued themselves with the devil, and increased their pay by working against the interest of the city.

By a system of their own they were enabled to follow the movements of an engineer so closely as always to avoid a surprise. For years they escaped suspicion. Their code of signals was so complete that the approach of an engineer was known long before his arrival, and the thieves thus had ample time to cover up their false work.

Signals usually came from the mouth of the shaft. The tunnel was lighted by electricity, and whenever the conspirators saw the lights grow alternately bright and dim three times in quick succession, they knew that the engineer was near at hand.

Perhaps since his last visit the masons had laid fifty lineal feet of lining without putting in the chamber above it or on its sides a single yard of rubble masonry. Between the lining and the limits of the excavations around it they left nothing but air, for which they received from the city $5 a cubic yard. Expensive air, that!

But now, when warned of his approach, they built very hurriedly a wall of masonry that entirely concealed the empty chamber, and when the engineer looked at the work he pronounced it well done. He suspected nothing. There stood the inspector, whose duty it was to protect the city from fraud, and there stood the rubble masonry.

A stout blow with a crowbar would have crushed the thin wall and revealed the fraud, but the blow was not struck. It did not seem necessary to strike it. The engineer's back once turned, the false work was continued till the next signal of his approach, when another partition wall was built.

Thus we had miles of air chambers above the brick lining of the aqueduct, some of them big enough to dance a quadrille in.

THE FIRST INVESTIGATION.

At last Mr. Gowen's suspicions were aroused. He had not the power to order the work stopped, and the contractors, confident of their influence with the commission, lorded it over him with a high hand. He met them half way, however, by holding back in his next estimate some $27,000 of the money alleged to be due them, a sum sufficient, he deemed, to cover their bad work.

This action precipitated a crisis. The contractors indignantly demanded his removal on the ground of incompetency, charging him with maliciously interfering with the work. An investigation was asked and granted, Mr. Rice, a firm supporter of Mr. Gowen, taking charge of it.

The investigation, begun at Tarrytown, in November, 1887, lasted several months, accomplishing little of practical value. In the following March, Mr. Rice obtained permission to make a thorough examination of the work.

Holes were punched in the lining, and in nearly every instance the drill met with no obstruction after passing through the three courses of brick. Lighted candles, pushed through the openings by means of a wire, continued to burn freely, illuminating the empty chambers. The engineers were vindicated. Stupendous frauds were revealed at every point. Tests of the construction were made with a steel sounding rod, which, by its peculiar ring when driven against the lining of the tunnel, indicated to a certainty whether the spaces above were filled with masonry or air. A record was kept of every hole drilled, together with the number of barrels of grout pumped through it. The total number of openings exceeds 225,000.

A CAMERA SPIRITED AWAY.

Spaces large enough to admit masons and material were cut in the arch, at intervals of about twenty feet, and through them thousands of cubic yards of loose rock were passed to be packed around the lining and afterward grouted with cement.

The thieves were shrewd enough to lay the first, or inner, course of brick with care, so that the inside of the tunnel is an exhibition of fine masonry. But there they drew the line. In some places the second and third courses were laid without cement enough to hold the bricks together; in others, where the specifications called for five courses in the key of the arch, and where five were paid for by the city, only three were laid.

Desirous of fortifying the commissioners with evidences of this bad work, one of the assistant engineers, an amateur photographer, went into the tunnel to take flash light pictures.

While engaged in the undertaking the man lost his camera, and the supposition is that it was spirited away. The contractors afterward presented the engineer with a new camera.

The grade of the aqueduct is very light, but it is continuous. The water finds its way from lake to reservoir by gravity alone, no pumping being required at any point. It is estimated that the stream will flow about two miles an hour. If the Croton gatehouse be opened at six A. M., the water will reach Central Park at ten P. M., a journey of sixteen hours.

Mr. Rice and the reporter moved a little slower, as they loitered on the way to inspect the work in all its phases; to rest themselves in the cool chambers over the arch, where they breathed air that cost $5 a cubic yard; to ramble through blow-offs and waste weirs; to climb up shafts and down them at the risk of breaking their necks; to watch the grouting "all the while," and discuss the momentous question, "Was O'Grady cheaper than cement?"

Their tour occupied them twenty hours. The gentle slope down which they walked is a fall of only 8 2-5 inches in the mile. The Croton gatehouse is 25 feet higher than the gatehouse at 135th Street, and 34 feet 4 inches higher than the Central Park reservoir.

STABILITY OF THE TUNNEL.

The tunnel tourists came across a score of masons filling air chambers with loose rock and patching the lining. Several new holes were being cut, and in observing this part of the work the reporter was enabled to form an opinion of the stability of the tunnel. In order to remove a brick from the wall a steel crowbar was required, on which two men hammered with all their might with six-pound sledges. It was not possible to get the brick out whole. The cement held it with so firm a grip that the bar was driven through it again and again before it would yield.

If this were a fair sample of the masonry in the lining, then it might be said that the tunnel is built for all time.

When the engineers complete the loose rock filling in the empty chambers and close all the interstices with grout, nothing short of an earthquake can injure the aqueduct.

No structure was ever examined with so scrupulous care or repaired so thoroughly. The frauds of the contractors can never be condoned, but they have been of incalculable benefit, inasmuch as the discovery of them has given to the city the most perfect conduit that the world ever saw. And it is safe to predict that future generations of engineers will bless them, for they have been eye-openers on a grand scale.

At Station No. 408+30, about eight miles from the gatehouse, the tourists detected a faint blue light ahead.

"Pocantico," said Mr. Rice and Mr. Gowen in a breath. Pocantico it was, 8,700 feet away. The hills overhead had been steadily receding. They now fell back altogether, and the aqueduct passed under Pocantico river. Then plunging again under the hills a distance of 3,000 feet it came to the surface in the Pocantico blow-off and waste weir, 9 1-4 miles from Croton dam. A beautiful stone structure marks the spot. Here is a great stone pier in the middle of the stream, having vertical grooves on either side, corresponding to grooves in the walls, in which stop planks are dropped to form a dam to turn the water out of the tunnel, through gates into the Pocantico river. The blow-off is much like a gatehouse, though far simpler. It is a convenient structure for letting the water out of the tunnel whenever the latter should need cleaning or repairing. Just before reaching it the aqueduct curves sharply to the left, then goes off on another tangent four miles in length.

The tourists climbed a ladder to the top of the blow-off to obtain a view of the country and a little fresh air. The Hudson was only a mile and a half to the west, but high hills obscured it. The journey was continued. The aqueduct bored under the hills immediately, and was soon 400 feet beneath the surface. For half a mile it was dry, but the tears from the weepers accumulated till they formed a stream, which grew every moment.

THE HEADLESS HORSEMAN.

"Sleepy Hollow," said Mr. Gowen, meditatively and speculatively.

The reporter looked up involuntarily and caught a memory glimpse of Ichabod Crane striding along the profile of a hill, with his clothes bagging and fluttering about him, a gaunt figure that one might easily have mistaken for the genius of famine descending upon the earth, or some scarecrow eloped from a cornfield. A great noise was heard in the tunnel down beyond the nebulous cone, and the imagination did not have to be strained to see the Headless Horseman of Sleepy Hollow dashing through the pitch-black corridor. The fearful hoof-clattering was followed by a fiendish yell, then there was a splash as horse and rider plunged into the miry meshes of Jay Gould's swamp. The tourists felt lonesome, and began forthwith to drown their melancholy in a flood of song. "Annie Laurie," "He's a Jolly Good Fellow," "The Soldier's Farewell," "Down in a Coal Mine," and "Home, Sweet Home," waked a wonderful echo. The effect was even grander than that produced by the wooden diaphragm near the Croton gatehouse. There must be another diaphragm here, the reporter thought, and Mr. Gowen said there was, though not a wooden one. It was determined to make a crucial test. So all stood still, with their candles behind them, while the reporter said in an ordinary tone:

"Hello!"

"Hello-a!" came back the clear reply.

"What are you doing there?"

"What-a do-a here-a?" said the echo.

"Capital," chorused the three.

"Capital-a," soloed the diapragbm.

"Seems to belong to the Italian school," said the reporter, who failed to appreciate the merits of the somewat peculiar pronunciation.

"Belong to Italiano school-a."

The echo suddenly began to do its own talking, and the language was so distinctly Italian that the tourists subsided. To judge from the jabbering that filled the tunnel, there might have been a hundred mouths going at once, all in a state of high excitement. Something unusual must have happened. Perhaps a poor fellow had lost his life.

The tourists quickened their pace and soon arrived at the bottom of shaft No. 11 A. It was covered at the top with two-inch plank, and only a few faint rays of sunlight struggled through the cracks. Not a person was in sight. Not a sound was heard. The reporter started on, but had not gone ten feet before the water was up to his thighs. Another step and it was running over his boot tops. The horseshoe section of the tunnel disappeared. In its place was a circular section, 14 feet 3 inches in diameter. It looked like a great pipe, and it bent downward so rapidly that if the reporter had ventured a few steps further he might not have been here to write this article. He would have been floundering in water eighty feet deep, for the aqueduct here went down that distance in order to go under Jay Gould's swamp, and all the tears from the weepers had collected in the depressed section, till it was filled to the brim.

As the tourists were not divers, they concluded to walk across the swamp in the broad light of day. So an exit was made at No. 11, a shaft eighty-four feet deep. As there was no bucket, it was necessary to scale a ladder, vertical and slippery. One edge of the platform covering the mouth had been raised about ten inches, and propped up with a brick, and through this aperture Mr. Rice squeezed first, then the reporter, then Mr. Gowen. A handful of Italians stood shivering in the nipping air, and as Mr. Gowen, in his wonderful seafaring toggery, appeared, an aged son of Italy, bristling with whisky and alarm, exclaimed:

"Hello-a! What-a this-a fellow? Dutchmano?"

Mr. Gowen overheard the remark, and the Italians were scattered with a wave of his hand. It turned out that these were the fellows who had cast obloquy on the echo. The water in the depressed section, acting as a diaphragm, had sent the voice of the tourists up the shaft, and the music had stirred the country for a mile around. The residents of East Tarrytown had heard it with dread, and were now standing on their doorsteps, looking anxiously toward the shaft. A week after the incident people were asking one another if anybody had learned the origin of those terrible sounds that came from the aqueduct.

GOULD'S SWAMP SIPHON.

The Gould's Swamp siphon is only 1,000 feet in length. Crossing it, the tourists tore up the planking over shaft No. 11 B and prepared to re-enter the tunnel. Here Mr. Gowen, who was nearing the end of his division, concluded to turn back, so Mr. Rice and the reporter proceeded without him. No. 11 B is no deeper than No. 11 A, but going down a vertical ladder is not as great fun as going up. However, the descent was safely made.

The water at the bottom was knee deep, but as the horseshoe section had reappeared, the walking on the invert was good. It is scarcely necessary to say that the water as it flows through the Gould Swamp siphon is under pressure. Indeed, wherever there is a circular section there is pressure. The horseshoe section, nearly twenty-three miles in length, is not under pressure. Where flowing at the rate of 318,000,000 gallons a day the water in it is not within eighteen inches of the key of the arch.

Fourteen and a half miles from the Croton gatehouse the tourists passed under Sawmill River, and two miles further on reached the blow-off and waste weir at Ardsley. The work from the beginning had been mile after mile of reconstruction and repair. The lining was never without its patchwork of new masonry, its grouting holes plugged with cement. Everywhere the silicate of magnesia in the cement had oozed from the joints, each drip forming a round spot on the wall, from which an enormous fantail spread outward and downward, giving the tunnel the appearance of a firmament studded with splendid comets. Through the weepers curious funguses had stolen, some white, some chocolate brown, some a yellow ocher, some oxide of iron, and entering the stream at different places had stratified it till it looked like a handsome satin ribbon. In one spot a fountain of crystal water bubbled up through a hole in the invert. A hundred feet away there was a weeper in the side wall, and when Mr. Rice placed his foot over the fountain, stopping it, the water instantly poured through the weeper, showing a strong underground stream.

At Sawmill River the tunnel curves to the right, and at Ardsley curves still further in the same direction. The Ardsley blow-off is simply another break in the aqueduct, for the purpose of emptying it. It is practically the same as the blow-off and waste weir at Pocantico. The water being dammed with stop plank is turned through gates into Sawmill River, which carries it to the Hudson.

Here the tourists came upon a grizzled veteran, clad from collar to heel in rubber. Above the collar and overspreading the chest was a long beard, nearly white. Above the beard was an ancient felt hat which had shaped itself like a cone, its crown having been pushed into a point and its brim pulled down, till there was no telling where the one ended and the other began. A critical examination revealed at the junction of hat and beard a pair of sparkling eyes. This figure held a lighted candle in one hand, and was evidently bent on journeying in the tunnel.

Mr. Rice rushed forward and shook the other hand, and then introduced the reporter to General James C. Duane, president of the Aqueduct Commission. The reporter, then and there, would have given $10 for the general's picture. Only those who have seen the fine old soldier in the tunnel can have the remotest conception of his makeup on this occasion. The general was excellent company and a rapid walker. The miles flew by at the rate of one and a half an hour. When conversation languished, the reporter blew upon his harmonica or tapped his tuning fork against the wall to test the pitch. Still the key of F major. At times the water seemed to raise or lower the pitch somewhat, according as it was deep or shallow, but the change amounted to less than a half note even in the most extreme cases.

The tourists were now in Alfred Craven's division, which extends from station No. 757 to the Harlem River, a distance of nearly fourteen miles, and includes work formerly under the charge of S. F. Morris. It is proper to state here that there were originally seven division engineers on the tunnel, and that now there are but three. Mr. Gowen's division was extended to include the division formerly under the charge of J. M. Wolbrecht. The division south of Harlem River is under E. Wegmann, Jr. Mr. Burbank's division covers reservoir construction, the great dam at Sodom being his principal work.

THROUGH A CEMETERY.

At station No. 900, some nineteen miles from the

gatehouse, the tunnel passes through Mount Hope Cemetery. But let not your heart be troubled on that account. The graveyard is nearly 200 feet above the aqueduct, and there are millions of cubic yards of filtering material between them. Besides, only fashionable people are buried there. This statement recalls the visit of a New Yorker to Philadelphia. Having tasted Quaker City water at the Continental Hotel, he remarked to the waiter:

"This water has a curious taste."

"Oh, yaas, sah," said the waiter, agreeably.

"Tastes as if it had seeped through a graveyard."

"Oh, yaas, sah."

"You confounded scoundrel! What do you mean by giving me such stuff to drink?"

"Oh, dat water am all right, sah. It flow froo de mos' 'ristocratic graveyard in de city."

At shaft No. 16 a tunnel inspector was met.

"I'd advise you not to try to reach the South Yonkers blow-off," he said. "The walking's very bad."

The reporter wanted some bad walking to vary the monotony, and so did Mr. Rice. General Duane declared he wouldn't be frightened back, so on the tourists went. The walking was bad, as bad as bad could be—half-leg deep in water and soft mud. The general propped himself against the wall from time to time as if on the point of giving up to fatigue, and the reporter was much concerned, but Mr. Rice whispered that the old soldier was equal to a hundred miles of such progress. Still, he seemed glad to sit down on a rough block of wood and partake of an excellent luncheon that Mr. Rice had brought along in a box. And when, having disposed of his share of eggs and sandwiches, he lighted his long-stemmed pipe, he looked the personification of comfort. When the blow-off was reached, he seemed perfectly fresh. Such endurance in a man of seventy-three years is little short of marvelous.

For half a mile at South Yonkers the aqueduct is on an embankment. The blow-off is similar to those at Pocantico and Ardsley, but considerably larger in appearance, as most of it is above ground. It is twenty-one miles south of Croton Dam and empties into Tibbett's Brook, and from that into the Harlem River through Van Cortlandt Lake. The same magnificent stonework is seen here as at the great gatehouse on the lake, every block of granite used in the construction having been cut to its required shape before leaving the quarry in Maine. All the gatehouses and blow-offs were built after designs made by the chief engineer, Mr. Fteley. They combine three most desirable qualities—utility, beauty, and economy.

General Duane retires at South Yonkers, and Division Engineer Craven takes his place. Mr. Craven used to be a United States naval officer. As an engineer he has a brilliant record. The contractors made the same fight on him as they made on Mr. Gowen, and, like Mr. Gowen, he has been vindicated. The worst work on the tunnel was done on sections No. 4 and No. 9, the former on Mr. Wolbrecht's division, now Mr. Gowen's, and the latter on Mr. Morris' division, now Mr. Craven's. On No. 9, where the repairs are still being made, the reporter was enabled to judge for himself the quality of the scamped work.

More than a year ago this entire section was turned over to the commissioners for final acceptance. It was reported complete and up to the mark. Investigation proved it to be unsound from one end to the other. Nearly every hole punched in the lining revealed fraud. Mr. Allen, one of Mr. Craven's assistants, joined the tourists at shaft No. 18½, and provided a ladder, by means of which the reporter ascended into the costly air chambers. In many of them he could stand erect and walk a considerable distance on the key of the arch. The thin walls, built to blind the engineer, had been broken, and through the apertures the reporter crawled on hands and knees from one chamber to another. There was one chamber in which the roof of the excavation was more than ten feet above the key of the arch. It had been filled with cord wood, and this had rotted till much of it could be squeezed into a pulp with the hand.

A MIDDAY MEAL OVER THE ARCH.

In another chamber the reporter found eleven masons eating their midday meal by the light of the smoking miners' lamps which they wore in their hats, lamps that looked like diminutive coffee pots with wicks in the spouts. These men were repairing the arch, the original masonry having been scamped to a shameful extent. The ladder was moved from place to place, and the reporter climbed through holes and walked through empty chambers till he was almost suffocated with the foul air. He asked himself over and over again, "How was it possible for such monstrous frauds to escape detection?" It is hard to believe that this work, so outrageously, so criminally bad, could have been reported as ready for acceptance by the city.

The repairs along here are seriously hindered by the action of the courts in refusing to dissolve a silly injunction which restrains the engineering corps from removing a sub-contractor who has become obstreperous and dictatorial. This man is said to be retarding the work; he ought to employ hundreds of laborers to push the repairs where he is only employing tens.

At station No. 1,267+25, about twenty-four miles from Croton Dam, the horseshoe section comes to an end, and the tunnel, assuming a circular form, 12 feet 3 inches in diameter, plunges down 120 feet below the grade line. The drift, as it is called, is just about steep enough to make a glorious toboggan slide. By turning himself loose a man goes down it at a lively pace. There is no water on the slope, and the acoustic properties are superb. The pitch has changed with the section, F major having remained behind with the horseshoe, while the circular lining hums industriously to the key of G.

At the bottom of the drift the tunnel resumes its normal grade and the water begins to grow deep. There is no walking now on the river bank. The bottom of the stream, the middle of the pipe, is the only safe place. The long boots are pulled up to their limit, and still the water finds its way over the tops. At length an old tramway appears, two six inch planks nailed three feet apart on short cross ties, which are sometimes ten feet apart. This structure floats on the surface till the foot strikes it, when down it goes to the bottom, wabbling and writhing and squirming like a sea serpent. Once under water the planks are obscured by mud, and the pedestrian who can always keep his footing on the springboard is a genius. If he makes a misstep he is immersed far beyond all expectations. He must pause frequently to give the boards time to float to the surface, so as to see where he is going to put his foot. There are several miles of this fun, long, slow, laborious miles. The feet weigh tons. To get them out of the water requires all the power in a person's body, but once out they are so light as to unbalance the head, which wants to go down as they bob up.

Mr. Craven and Mr. Allen left the tunnel at shaft No. 22, but Mr. Rice and the reporter kept on to Harlem River, passing a steam pump at No. 23 and going on down to No. 24, where circumstances beyond their control invited them to turn back. They reached the mouth of the great siphon, which carries the water of the aqueduct under the river, 307 feet below the level of the tide, but the siphon being full, and shaft No. 24 being inaccessible, the tourists were obliged to retrace their steps—oh, such weary steps!—to No. 23, where they found a ladder which led them to the surface of the ground. The confined air near No. 24 was dangerously foul, and the reporter was troubled with a slight head swimming. Mr. Rice, long used to tunnels, suffered no inconvenience. The removal of soot from the reporter's face blackened forty gallons of hot water. He was five days clearing his lungs of the stuff.

(*To be continued.*)

THE CABLE RAILWAY TUNNEL UNDER THE CHICAGO RIVER, CHICAGO, ILL.

THROUGH the courtesy of Mr. Samuel G. Artingstall, C.E., the chief engineer, we are enabled to present sections and the plan and profile of this interesting work.

The tunnel is being built by the West Chicago Street Railway Company, and, as shown, is being fitted for double track cable traction. It crosses the Chicago River about 150 ft. north of Van Buren Street (see Fig. 1) and at shore ends it passes under several large buildings, requiring underpinning and essentially new foundations over the tunnel. The plan and profile show with sufficient clearness the general position of the tunnel with reference to the river and adjoining streets and buildings.

The tunnel will be lined with hard-burned brick laid as hereinafter described. Utica cement is specified for use when natural cement is to be employed. The concrete, however, is to be made of Portland cement mortar, with sand, and broken limestone in cubes not exceeding 3 in. in any dimension. The concrete mortar will be one part cement to three parts sand by measure, and to this mortar six parts of the broken stone is to be added. This concrete is to be spread in successive 4 in. layers and thoroughly rammed with rammers 4 in. in diameter and weighing not less than 20 lb. each. The face stone, when used, is to be "Buff Bedford," with beds and joints planed or bush-hammered, and the rubble stone will be Joliet limestone as large in size as possible.

The tunnel from the west line of Franklin to the east line of Clinton Street will be 1,513 ft. long, with the dimensions shown on the several sections. The gradients are given on the accompanying profile. The line is located upon private property, and besides passing under the buildings before referred to, also crosses under the tracks of the Pittsburg, Fort Wayne & Chicago R.R. and the Chicago, Burlington & Quincy R.R. on the approach to the Union Depot.

The contractors for building the tunnel are responsible for the safety of the buildings, etc., under which the tunnel is driven. The contract generally specifies that before any work on the tunnel is commenced, all buildings must be underpinned by extending the foundations downward below the level of the tunnel bottom, according to such plans as the engineer may devise and the conditions demand. All trenches are to be excavated in short lengths and securely supported by close oak sheeting, struts, braces, etc.; this sheeting shall be calked in such places where water may be troublesome, or there is any liability of settlement by escape of semi-liquid material.

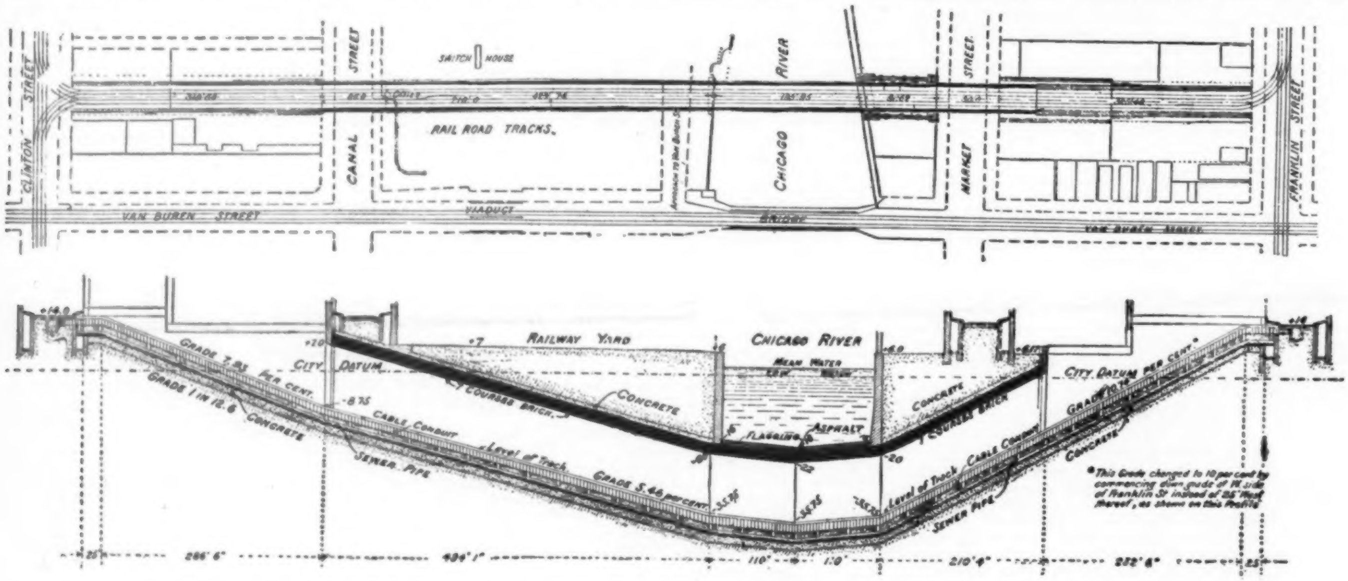
The Springer Building, between Clinton and Canal Streets, will have its west front supported on steel girders resting on stone piers, with footings of Joliet limestone. The east front will be carried on steel girders resting on piers built of Anderson pressed clinker or Brand brick laid with very close joints in Utica cement mortar; concrete foundations will support these piers. The second floor of the building, and the first floor on Canal Street, will also be carried on steel girders resting on common brick walls carried clear to the second story and supported on the side walls of the tunnel approach.

The Altgelt Building, between the river and Market Street, will require especial care in supporting it during the progress of the work. The river and Market Street fronts will be carried on steel girders on Anderson brick piers, laid in Portland cement mortar. The foundations under the piers on the river front will be of concrete, 10 by 20 ft., capped at the dock line with Bedford stone, 2 ft. thick. The Market Street piers will be of brick and a concrete base. The side walls of the building will be supported on cast iron cylinders, indicated in the plan. The cylinders on the north side will be 6 ft. in diameter, and those on the south side 7 ft. in diameter, with metal 1¼ in. thick, and 4½ in. internal flanges, bolted together by 1⅛ in. bolts, spaced 5 in. apart. These cylinders will be sunk by excavating the earth inside and forcing them into the ground.

They will be located under the center of the wall, filled with concrete after the base has reached firm bottom below the tunnel level, and each capped on top by a granite block, 2 ft. thick by 4 ft. wide and 6 or 7 ft. long. Between these cylinders will then be turned brick arches, backed and underpinned to existing walls by brick masonry of Anderson clinker pressed brick laid in Utica cement mortar in an alternate header and stretcher bond.

After these cylinders are in place, and the walls of the building secure, the floors will be supported by temporary trusses until the tunnel is finished. After this the cast iron columns supporting the floors will be replaced on piers of concrete and timber cribwork, as shown at the bottom of the inset illustration. This cribwork will be used for the purpose of distributing the weight over the surface of the tunnel while the concrete is wet. If sufficient time can be gained before the load is applied, its use will not be necessary.

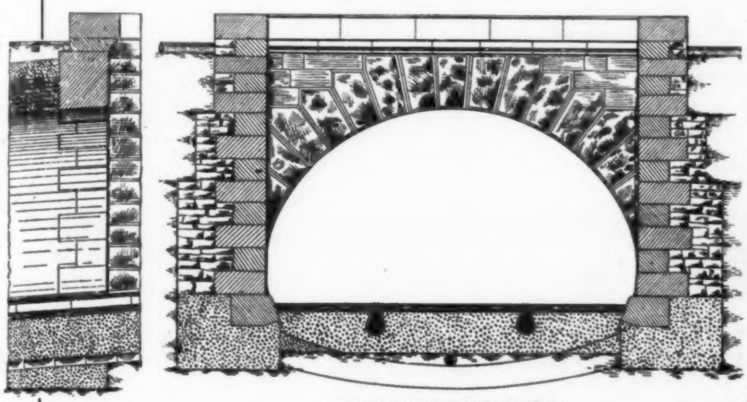
The open approaches will be faced with Bedford stone in regular courses ranging from 2 ft. to 18 in. in depth, and laid with an alternate header and stretcher bond. The backing will be of Joliet limestone in courses of the same thickness as the face. Portland cement is alone to be used in this portion of



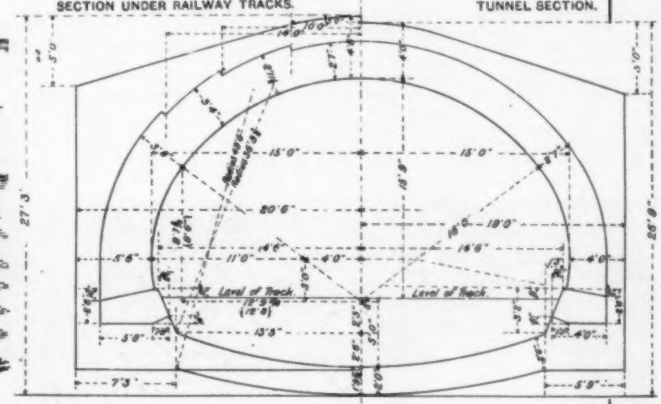
PLAN AND PROFILE OF THE CABLE RAILWAY TUNNEL UNDER THE CHICAGO RIVER.—SAMUEL G. ARTINGSTALL, Engineer.

CABLE RAILWAY TUNNEL UNDER RIVER NEAR VAN BUREN STREET, CHICAGO.

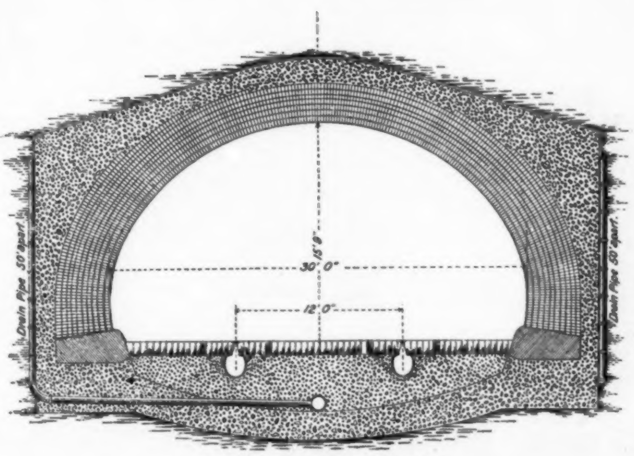
WEST CHICAGO STREET R. R. CO. SAM'L G. ARTINGSTALL, CHIEF ENGINEER.



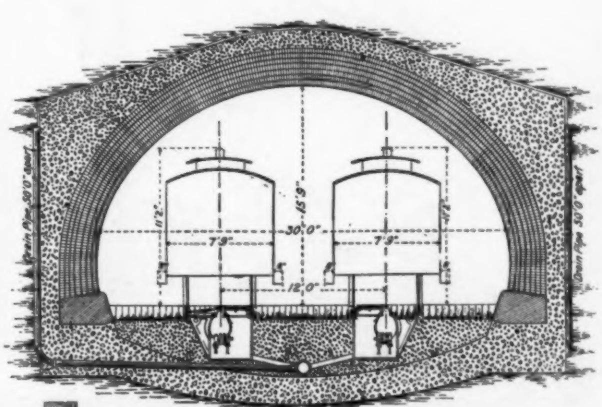
ELEVATION OF TUNNEL PORTAL



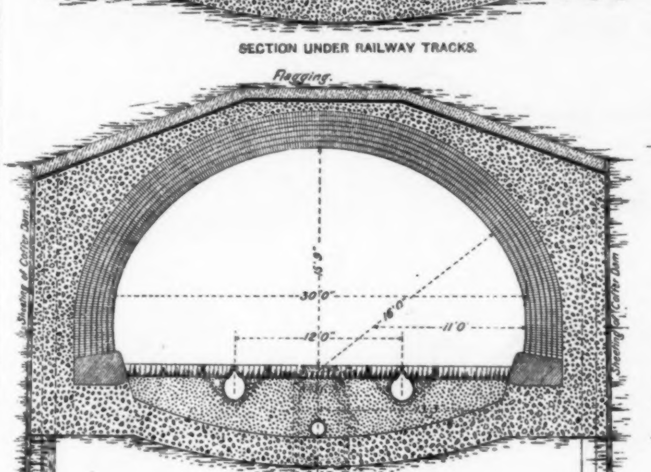
SECTION SHOWING DIMENSIONS.



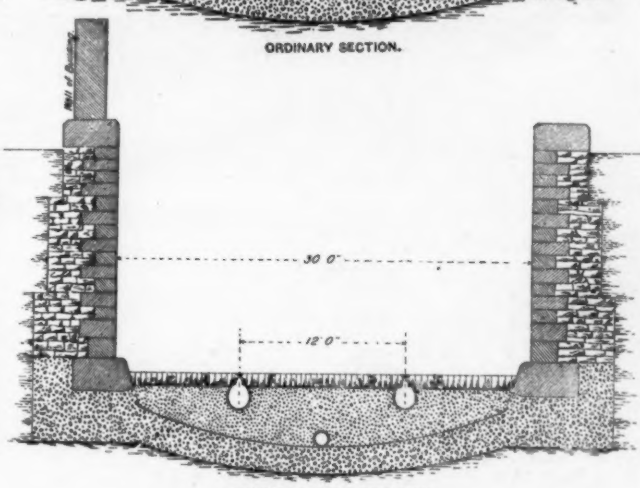
SECTION UNDER RAILWAY TRACKS.



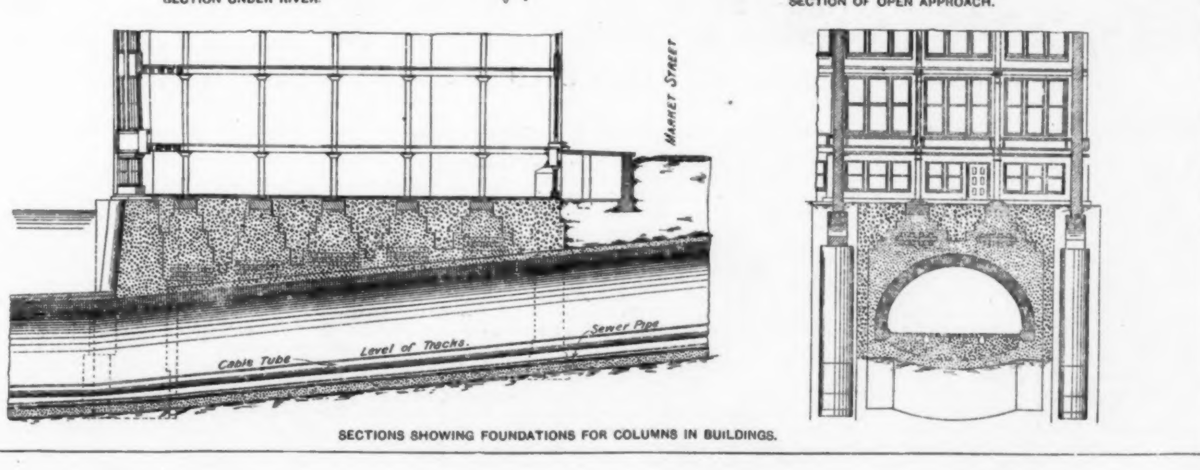
ORDINARY SECTION.



SECTION UNDER RIVER.



SECTION OF OPEN APPROACH.



SECTIONS SHOWING FOUNDATIONS FOR COLUMNS IN BUILDINGS.

the work, and the foundations below them will be of Portland cement concrete.

The tunnel portal will be made of Bedford stone, as shown in the elevation on inset illustrations. The tunnel proper will be of brick masonry, in seven rings, or 32 inches thick; excepting a length of 210 ft., under the railway tracks, where the thickness is increased, as shown on the drawings. The bricks will be laid longitudinally with the tunnel, with edges toward the center and toothing joints. The joints must be perfectly filled by pressing the brick into the mortar, and not made by attempting to force the mortar between the bricks. The joints between the courses shall not exceed one-half inch in thickness, and between the rings the joints shall not be less than one-half inch.

The tunnel masonry will be laid generally in Utica cement mortar. But the bricks in the three outer rings, under the river and for 100 feet on each side, a total distance of 420 ft., and in the two outer rings in the rest of the tunnel, will be laid in and grouted with asphalt cement mortar. This mortar is to be made of pure Trinidad asphalt and gypsum, with generally one part asphalt to three parts gypsum; to be mixed on the ground and furnished hot, ready for use in small quantities as required. No remelting of set or cold asphalt mortar is permitted. The invert, the backing, and the filling over the haunches and crown of the tunnel will be Portland cement concrete well rammed in place.

For the river section the top of the concrete filling will be covered with one inch in thickness of asphalt mortar, made as before described, and in this will be embedded large flagstones, 12 inches thick, with the joints grouted with asphalt mortar. The dock walls are to be built of Portland cement concrete, faced with Bedford stone, in 2 foot courses, and surmounted by a coping 2 feet thick by 8 feet wide.

Under the center line of the tunnel there will be a 12 inch drain pipe, with manholes for cleaning 200 feet apart. Drain tiles, 4 inches in diameter, will also be laid outside of the tunnel and about 50 feet apart, and these will connect with 4 inch cast iron pipe leading to the main drain. The main drain discharges into a sump on the east side, at which point there is a drainage pump and a 6 foot brick well leading to the surface.

The river portion will be built in a coffer dam, one-half at a time, and the specification requires the contractor to provide at all times a free and open channel for vessels. The contractor will not be permitted to draw any piles, sheeting, etc., used in this portion of the work, but he must remove all obstructions and cut off all timbers at least 18 feet below city datum.

The plans for this tunnel have been prepared by Mr. Samuel G. Artingstall, C.E., who is the engineer of the work. The contract for building, which has just been let to Fitzsimmons & Connell for the sum of $750,000, calls for its completion by Feb. 1, 1892. This contract does not include the paving, tracklaying, and filling over the invert under the tracks. Work has already been commenced on the coffer dam at the west end of the tunnel at Clinton street. Mr. Charles Weston, who has been appointed resident engineer, was lately resident engineer of the Lake View tunnel under Lake Michigan, and Mr. H. Leach has succeeded him in that work.—*Engineering News.*

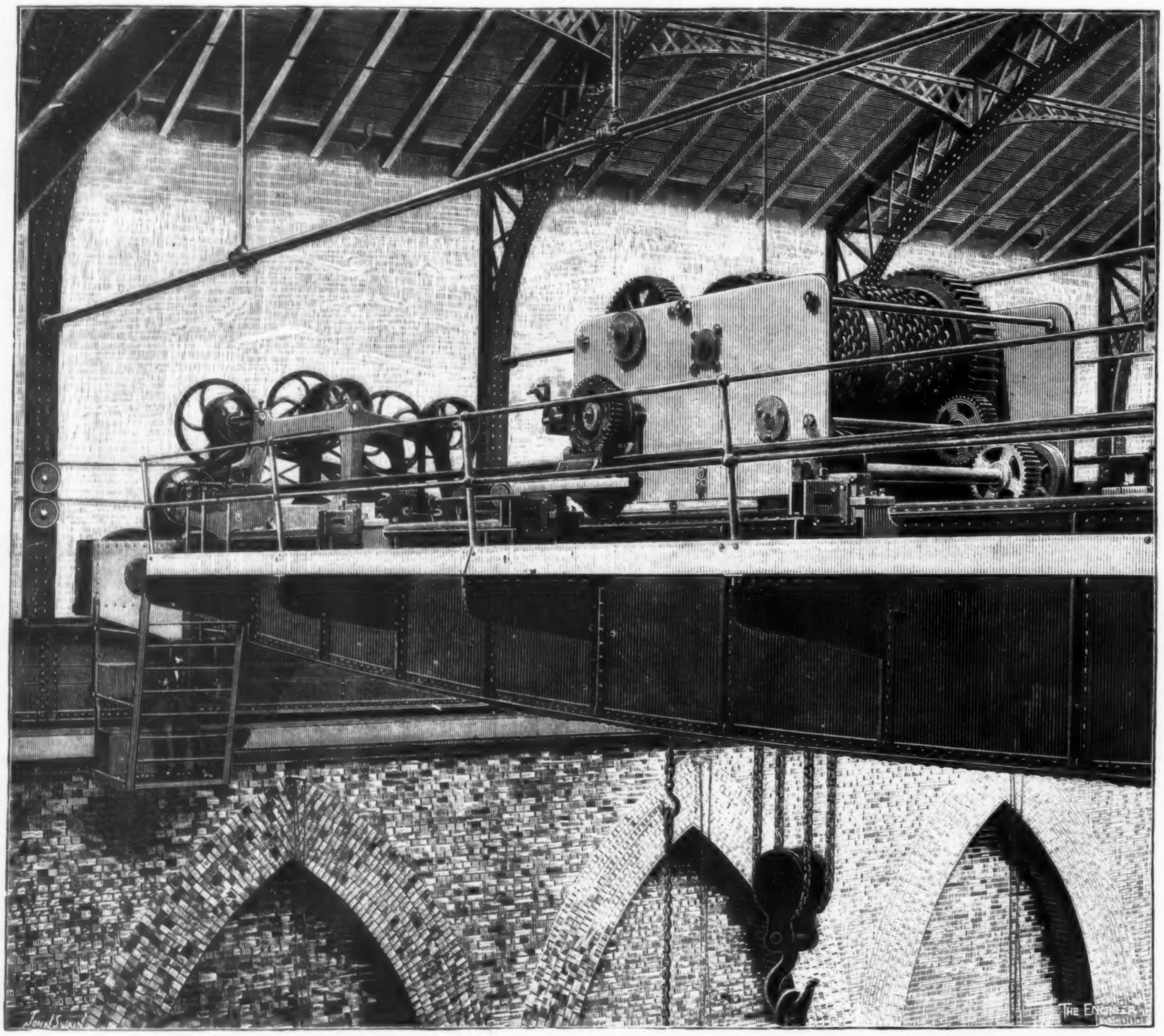
TWENTY-FIVE TON OVERHEAD ROPE POWER TRAVELING CRANE.

The illustration shows a twenty-five ton overhead rope power traveling crane, 62 ft. span, made to the order and from the instructions of Messrs. Hick, Hargreaves & Co., Bolton, by Messrs. Vaughan & Son, West Gorton, Manchester, for the Deptford Station of the Electric Storage Supply Corporation, London. It is designed to deal with heavy or light loads in an expeditious manner, and can be traveled along the shop, the crab also traveling along the crane, and the load hoisted at one moment or separately as required. The speed of crane traverse is 80 ft. per minute. The girders and wheel boxes consist of wrought iron plates, angles, tees, and steel rails, all riveted together. Each wheel box is fitted with two large steel-tired traveling wheels keyed on steel axles, running in gun metal bearings.

The crab, consisting of steel plates strongly stayed together, is mounted on four traveling wheels; the chain barrel has a right and left hand groove, in which the hoisting chain coils equally, thus distributing the load equally on each girder. Cross traverse and hoisting motions are conveyed to the crab by two double grooved steel shafts carried on Vaughan & Foster's patent tumbler bearings; on each shaft a steel worm is fitted and carried by a cast iron worm box, these worms gearing into gun metal worm wheels.

The tumbler bearings consist of vertical slide, horizontal wedge, cast iron casing, cast iron spout, stop pin, cast iron brackets bolted to crane girder, friction roller, "plow" or kicker plate with channel attached to crab, gun metal bearing. When the crab approaches the shaft support, the "plow" engages the friction roller, and draws out the horizontal wedge. This movement causes the vertical slide to move downward to the bottom of its travel, where it remains at rest while the worm box is passing over, when the plow again engages the roller, and this time forces the horizontal wedge inward, and in its turn the vertical slide upward. Motion is transmitted to the crane by the cotton driving rope to the three countershafts on the crane headstock, and from them by means of open or cross belts to the three shafts extending the full length of crane. These belts are under the full control of the attendant, who from his position in the turret or cage has a full view of the load and of the floor.

The driving rope, which is specially made for crane driving, is carried the full length of the building on gallows pulleys running on self-oiling spindles, and is held in a taut condition by a self-adjusting tension slide at one end of the building, and balanced by weights. The attendant can stop or start the rope from any part of the track by means of an endless hand cord. The load is carried from the large barrel and from the suspension bar by four strands of best tested crane chains, the hook—of which we give an enlarged view—possessing several points of interest. The head of the hook, to insure greater security, is forged solid with the shank, and is carried under the head, as illustrated, by a series of cast steel conical rollers. The friction caused in turning the suspended load is in this manner reduced to a minimum. The shafts throughout the crane are made of mild steel, and all run in gun metal bearings.—*The Engineer.*



TRAVELING CRANE, DEPTFORD ELECTRIC LIGHTING STATION.

A TELEGRAM to the Philadelphia *Press* states that a delegation from Delaware and Maryland appeared recently before the River and Harbor Committee of the House to advocate the construction of an inland ship canal between Chincoteague Bay and Delaware Bay. This is an old project, but it is to be pressed with renewed vigor upon the attention of the House this year. The ship canal can be constructed, it is estimated, at a cost of only $300,000. Congress will be asked to appropriate $100,000 this year to begin the work. This canal, when finished, will afford shelter for vessels in the harbor of Lewes, and will also be of great commercial value as a waterway. It would be of immense strategic value in time of war. Plans for the canal have been approved, and the appropriation is recommended by the chief engineer of the army.

ELECTRIC LIGHTING OF THE BRITISH MUSEUM.

THE introduction of the electric light in the galleries of the British Museum, the eastern and western parts of which, alternately, are now opened to the public in the evenings, is pronounced a complete success. Both arc and glow lamps are employed, the former in the galleries on the ground floor, containing Greek and Roman sculpture, the Elgin marbles, and Assyrian and other antiquities, as well as in some of the galleries on the upper floor. The glow lamps have been fixed in the long suite of bronze and vase rooms on the west, and in the ethnographical gallery on the east of the upper floor.

In the galleries on the ground floor there are 69 arc lamps of various powers, while on the upper floor there are 57 arc and 627 glow lamps. In addition to these there are five large arc lamps in the reading room, six in the courtyard, and upward of 200 glow lamps in the offices and passages. The current required to work the lamps is generated by four Siemens dynamo machines, which are connected to a general switchboard in the engine room, by means of which they can be put to work in parallel to any or all of the circuits. The switchboard is fitted with instruments indicating the current given off by each dynamo, and four circuits are led from it round the museum—two for the upper and two for the lower floor. The main wires are laid outside the building. In order to insure safety and to guard, as far as possible, against failure of light, the motive power is in duplicate. The four dynamos are driven in pairs, each pair by a separate engine, with a separate countershaft. Each engine has a separate steam pipe in direct communication with the boilers, and there is ample reserve of boiler power. The power of the engines and dynamos is so adjusted that each of the two sets is capable of working the whole of the lamps in those galleries proposed to be lighted on any one evening, the other set standing by ready to work. In order to work, if required, at half power, or to provide half light for the galleries, the lamps are connected in pairs alternately, so that, half of the number being cut off, the light of the other half remains evenly distributed. The engines have been supplied and erected by Messrs. Marshall, Sons & Co., of Gainsborough, and the electrical work executed by Messrs. Siemens Brothers & Co.—*Illustrated London News.*

ELECTRIC LIGHTING OF THE BRITISH MUSEUM.

THE BETTERMENT AND WORSEMENT PRINCIPLE.

IN judging of the Strand Betterment scheme, says a correspondent of the London *Times*, aid is derived from considering what has hitherto been the mode of compensating owners and other persons whose interests are appropriated or injured in the carrying out of public improvements. The clauses round which the controversy turns do not, of course, stand or fall according as they square with past legislation; but some of our correspondents insist that it is no real novelty in principle, while others argue the contrary; and the point is not altogether unimportant. It is well to see how far it is true that "the powers of the Strand Bill neither repeal, alter, nor modify any existing law, nor impose any special tax."

In private acts of very ancient date are provisions for compensation, elaborate, carefully drawn, and recognizing the right to recompense for such indirect damage as injuries by severance. As Mr. Clifford remarks in his history of private legislation, with reference to acts passed in the reigns of Henry VIII. and Elizabeth, the principles of compensation then adopted were much the same as those now in force. With endless variety of phraseology, descriptive of the recompense to be made, the legislature, in the many private acts on the subject before the Lands Clauses Consolidation Act, adhered to the principle that a public end, however good, did not justify a private wrong; that the owner and occupier were to be treated as if they had been wrongfully dispossessed or disturbed in their enjoyment; and that they were to be compensated very much in the same way as if they had brought an action for damages.

The Lands Clauses Consolidation Act, 1845—at once one of the most complex and successful of statutes—was passed to bring about uniformity as to the acquisition of land for public undertakings. It contains elaborate machinery as to the mode of assessing compensation in the case of "the purchase of land otherwise than by agreement" and of land being "injuriously affected." It is almost silent as to the principle upon which arbitrators or juries are to proceed. But a long course of decisions has cleared up most doubts on the subject, and has laid down certain clear rules—that as to lands purchased, the compensation must be calculated in the same way as if the owner had brought an action for being dispossessed; that the recompense must be assessed once for all; that as to land "injuriously affected," but not taken, the owner cannot recover unless he could have brought an action had the works not been authorized by parliament; and that he may be unable to get any indemnity for serious, irreparable, personal injuries or damage to trade or business for which he might have brought an action at common law.

This last reservation ought to be remembered by those who criticise the operation of the act and complain that owners get under it much more than they deserve. Juries and arbitrators do not take into account in compensating the owner of parcel A the indirect benefits which accrue to him as owner of parcels B and C. An unwritten rule recognizing an addition of 10 per cent. as a bonus for compulsory purchase has grown up. But it is only fair to bear in mind that there is another side to the matter; that mischief for which there is no remedy is sometimes done; and that the courts have said—somewhat arbitrarily, in the opinion of some eminent judges—that there shall be no compensation for certain indirect effects of the appropriation of land for public purposes. Notwithstanding the natural resistance to some decisions, questionable in policy, but undoubtedly binding, it may be the clear result of the law as to "injuriously affecting" that a score of tradesmen are ruined by improvements for which they are unable to obtain a farthing compensation.

The next important change in the history of the legislation related to superfluous land. Parliament was naturally jealous of the powers of corporations authorized to acquire land compulsorily. It took care that, under cover of a charter or act for one purpose, a corporation should not engage in another business; for instance, that a railway company should not become a large landowner. In early acts empowering the purchase of land—and the same policy is still pursued—a right of pre-emption is reserved to adjoining owners; if this power is not exercised, the promoters are required to dispose of their superfluous lands within ten years. This restriction worked injustice in some cases, especially when the Metropolitan Board of Works and other public bodies sought to open new streets in crowded districts. The municipality or other public body had no power to acquire more than the area required for the proposed highway.

The new frontagers reaped the full reward of the improvements, and were generally remunerated twice; first directly, and secondly indirectly, in the enhanced value of the property not expropriated. But during the last thirty years many private acts permitting promoters to purchase land considerably in excess of their strict requirements have been passed, with a view to enable them to reimburse themselves for their outlay by selling the superfluous land, which has been enhanced in value by the improvements. The best remembered case, that as to which the principle was fully debated, was the Metropolitan Street Improvements Bill, 1877. The policy which was then adopted, notwithstanding the opposition of the House of Lords, was repeated in other measures, and has become a recognized part of parliamentary law.

The next change took place in regard to the purchase of land for the purposes of Mr. Torrens' and Lord Cross' acts. The former acts proceeded upon the principle that houses unfit for human habitation ought to be closed, demolished, and rebuilt. The latter dealt with whole areas judged to be beneath a proper sanitary standard; the sanitary authority intervened as purchaser, and proceeded to carry out a scheme of reconstruction. It would be intolerable if an owner could profit by his own wrong; and in the Artisans' Dwellings Act, 1875, the valuator was directed to give "the fair market value as estimated at the time of the valuation being made of such lands and of the several interests in such lands (so as to exclude improvements made for the express purpose of increasing the amount of compensation), due regard being had to the nature and then condition of the property and the probable duration of the buildings in their existing state, and to the state of repair thereof (elements which a valuator ought to take into account, as appears by the cases under the Lands Clauses Consolidation Act), and all circumstances affecting such value, without any additional value in respect of compulsory purchase (thus excluding the usual 10 per cent. premium for compulsory purchase) of an area or of any part of an area of which an official representation has been made," etc. It was found that these restrictions did not prevent owners from getting compensation swelled to some degree by reason of their own shortcomings; and the Artisans' Dwellings Act, 1882, still further cut down the compensation by adding the

words: "In the estimate of the value of the said lands or interests in the said section (section 19 of the act of 1875) in that behalf mentioned, any addition to or improvement made after the publication of an advertisement in pursuance of section 6 of the said act, stating the fact of the improvement scheme having been made, shall not (unless such addition or improvement was necessary for the maintenance of the property in a proper state of repair) be included, nor in the case of any interest acquired after the said date shall any separate estimate of the value thereof be made so as to increase the amount of compensation to be paid for the land, and the words 'all circumstances affecting such value' in the said section are hereby repealed."

To what precise extent these words affect the usual basis of compensation is not clear; the probability is that they are of little consequence. It is only fair to add that in the same act, section 8, is the following provision overlooked by our correspondents: "Where in the opinion of the arbitrator the demolition of an obstructive building adds to the value of such other buildings as are in that behalf mentioned in this section, the arbitrator shall apportion so much of the compensation to be paid for the demolition of the obstructive building as may be equal to the increase in the value of the other buildings among such other buildings respectively, and the amount apportioned to each such other building in respect of its increase in value by reason of the demolition of such obstructive building shall be deemed to be private improvement expenses, etc. (subject to the provisions of the Public Health Act, 1875)." This section and the corresponding provisions in the Public Health Act are perhaps the closest approximations to the Strand scheme.

In 1886 a bill was introduced, but not proceeded with, for the purpose of still further curtailing compensation in the case of municipal corporations. Its professed object was to enable municipal corporations "to give evidence in any inquiry relating to the amount of compensation payable to the owner for lands so required as to the increased value which would accrue to other adjoining or neighboring land belonging to the same owner by reason of the execution of authorized undertakings and works." Under the existing law arbitrators and juries are not permitted to take into account both sides of the question. The bill—in every way a crude measure—was intended, it was stated, to "assimilate the law of England in this respect to that of other European and American states." This, as may be seen by a glance at such works as Mr. Stimson's "American Constitutions" and Mr. Redfield's treatise on railways, is scarcely accurate. Legislation varies in the different States of the Union. But no mean authority, Mr. Sedgwick, is no doubt right in saying in the classical American work on the subject of "Damages," with reference to compensation for injuries occasioned by public improvements, that "no deduction is to be made from the landowner's damages on account of the general advantage from the improvement in which he participates." The text of Dalloz (expropriation) is no less precise on the subject: "Le jury, dans son estimation de l'immeuble frappé d'expropriation, ne doit pas tenir compte de l'augmentation de valeur que l'entreprise des travaux a pu donner aux terrains."

Such is a short summary of the history of the law of compensation. The whole basis of it hitherto has been the existing law of damages. Two principles, speaking generally, have been supreme. First, the person dispossessed or injuriously affected recovers what he would have recovered in an action. This has sometimes the effect of swelling unduly the compensation. But occasionally it leaves an owner without a remedy for injuries distinctly appreciable. The second principle upon which parliament has, with few exceptions, proceeded is to deal with the subject by general legislation, and not by *privilegia*. Whatever may be the merits of the betterment clauses in the Strand scheme, whatever be the case for altering the present tribunals for assessing compensation—and our correspondents who agree in nothing else agree as to this point—the scheme is a distinct departure from both these principles. Perhaps the discussion will lead to an improvement in the practice, if not the principles, as to fixing compensation. No one acquainted with the working of the present system—no one who has looked into a bill of costs in proceedings under the Lands Clauses Consolidation Act and seen the preposterous fees given to counsel and surveyors—can doubt that the time has come for a change.

[Nature.]

ON THE CAVENDISH EXPERIMENT.

In the last number of the Proceedings of the Royal Society (vol. xlvi., p. 253) I have given an account of the improvements that I have made in the apparatus of Cavendish for measuring the constant of gravitation. As the principles and some of the details there set out apply very generally to other experiments where extremely minute forces have to be measured, it is possible that an abstract of this paper may be of sufficient interest to find a place in the columns of *Nature*.

In the original experiment of Cavendish (Phil. Trans., 1798, p. 469), as is well known, a pair of small masses, *m m*, Fig. 1, carried at the two ends of a very long but light torsion rod, are attracted toward a pair of large masses, M M, thus deflecting the arm until the torsion of the suspending wire gives rise to a moment equal to that due to the attraction. The large masses are then placed on the other side of the small ones, as shown by the dotted circles, and the new position of rest of the torsion arm is determined. Half the angle between the two positions of rest is the deflection produced by the attracting masses. The actual force which must be applied to the balls to produce this deflection can be directly determined in dynamical units when the period of oscillation and the dimensions and masses of the moving parts are known. In the original experiment of Cavendish, the arm is six feet long, the little masses are balls of lead two inches in diameter, and large ones are lead balls one foot in diameter. Since the attraction of the whole earth on the smallest balls only produces their weight, *i. e.*, the force with which they are attracted downward, it is evident that the balls, M M, which are insignificant in comparison with the size of the earth, can only exert an extremely feeble attraction. So small is this that it can only be detected when the beam is entirely inclosed in a case to protect it from draughts; when, further, the whole apparatus is placed in a room into which no one must enter, because the heat of the body would warm the case unevenly, and so set up air currents which would have far more influence than the whole attraction to be measured; and when, finally, the period of oscillation is made very great, as, for instance, five to fifteen minutes. In order to realize how small must be the force that will only just produce an observable displacement of the balls, *m m*, it is sufficient to remember that the force which brings them back to their position of rest is the same as the corresponding force in the case of a pendulum which swings at the same rate. Now a pendulum that would swing backward and forward in five minutes would have to be about 20,000 meters long, so that in this case a deflection of one millimeter would be produced by a force equal to 1/20,000,000 of the weight of the bob. In the case of a pendulum swinging backward and forward once in fifteen minutes the corresponding force would be nine times as small, or 1/180,000,000 of the weight.

In spite of the very small value of the constant of gravitation, Cavendish was able, by making the apparatus on this enormous scale, to obtain a couple which would produce a definite deflection against the torsion of his suspending wire.

These measures were repeated by Reich (*Comptes Rendus*, 1837, p. 697), and then by Baily (*Phil. Mag.*, 1842, vol. xxi., p. 111), who did not in any important particular improve upon the apparatus of Cavendish, except in the use of a mirror for observing the movements of the beam.

Cornu and Baille (*Comptes Rendus*, vol. lxxvi., p. 954, vol. lxxxvi., pp. 571, 699, 1001) have modified the apparatus with satisfactory results. In the first place they have reduced the dimensions of all the parts to about one-quarter of the original amount. Their beam, an aluminum tube, is only ½ meter long, and it carries at its ends masses of ¼ pound each, instead of two pounds, as used by Cavendish. This reduction of the dimensions to about one-quarter of those used previously is considered by them to be one of the advantages of their apparatus, because, as they say, in apparatus geometrically similar, if the period of oscillation is unchanged, the sensibility is independent of the mass of the suspended balls, and *is inversely as the linear dimensions*. I do not quite follow this, because, as I shall show, if all the dimensions are increased or diminished together, the sensibility will be unchanged. If only the length of the beam is altered, and the positions of the large attracting masses, so that they remain opposite to, and the same distance from, the ends of the beam, then the sensibility is inversely as the length. This mistake—for mistake it surely is—is repeated in Jamin's "Cours de Physique," tome iv., ed. iv.,

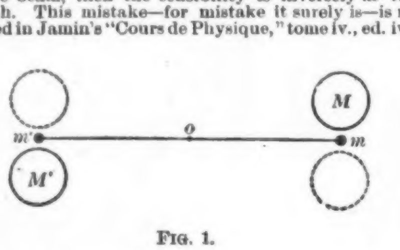


Fig. 1.

p. 18, where, moreover, it is emphasized by being printed in italics.

The other improvements introduced by Cornu and Baille are the use of mercury for the attracting masses, which can be drawn from one pair of vessels to the other by the observer without his coming near the apparatus, the use of a metal case connected with the earth to prevent electrical disturbances, and the electrical registration of the movements of the index on the scale, which they placed 560 centimeters from the mirror.

The great difficulty that has been met with has been the perpetual shifting of the position of rest, due partly to the imperfect elasticity or fatigue of the torsion wires, but chiefly, as Cavendish proved experimentally, to the enormous effects of air currents set up by temperature differences in the box, which, with large apparatus, it is impossible to prevent. In every case the power of observing was in excess of the constancy of the effect actually produced. The observations of Cornu are the only ones which are comparable in accuracy with other physical measurements, and these, as far as the few figures given enable one to judge, show a very remarkable agreement between values obtained for the same quality from time to time.

Soon after I had made quartz fibers, and found their value for producing a very small and constant torsion, I thought that it might be possible to apply them to the Cavendish apparatus with advantage. Prof. Tyndall, in a letter to a neighbor, expressed the conviction that it would be possible to make a much smaller apparatus in which the torsion should be produced by a quartz fiber. The result of an examination of the theory of the instrument shows that very small apparatus ought practically to work, but that in many particulars there is an advantage in departing from the arrangement which has always been employed, conclusions which experiment has fully confirmed.

As I have already stated, the sensibility of the apparatus is, if the period of oscillation is always the same, independent of its linear dimensions. Thus, if there are two instruments in which all the dimensions of one are n times the corresponding dimensions of the other, the moment of inertia of the beam and its appendages will be as $n^5 : 1$, and, therefore, the torsion must be as $n^5 \cdot 1$. The attracting masses, both fixed and movable, will be as $n^3 : 1$, and their distance apart as $n : 1$. Therefore, the attraction will be as n^6/n^2 or $n^4 : 1$, and this acting on an arm n times as long in the large instrument as in the small; therefore the moment will be as $n^5 : 1$; that is in the same proportion as the torsion, and so the angle of deflection is unchanged.

If, however, the length of the beam is only changed, and the attracting masses are moved until they are opposite to, and a fixed distance from, the ends of the beam, then the moment of inertia will be altered in the ratio $n^2 : 1$, while the corresponding moment will only change in the ratio of $n : 1$; and thus there is an advantage in reducing the length of the beam until one of two things happens: either it is difficult to find a sufficiently fine torsion thread that will safely carry the beam and produce the required period—and this, I believe, has up to the present time prevented the use of a beam less than ½ meter in length—or else, when the length becomes nearly equal to the diameter of the attracting balls, they then act with such an increasing effect on the opposite suspended balls, so as to tend to deflect the beam in the opposite direction, that the balance of effect begins to fall short of that which would be due to the reduced length if the opposite ball did not interfere. Let this shortening process be continued until the line joining the centers of the masses, M M, makes an angle of 45° with the line, *m m*; then, without further moving the masses, M M, a still greater degree of sensibility can be obtained, provided the period remains unaltered, by reducing the length of the beam, *m m*, to half its amount, so that the distance between the centers of M M is $2\sqrt{2}$ times the new length, *m m*, at which point a maximum is reached.

It might be urged against this argument that a difficulty would arise in finding a torsion fiber that would give to a very short beam, loaded with balls that it will safely carry, a period as great as five or ten minutes, and until quartz fibers existed there would have been a difficulty in using a beam much less than a foot long, but it is now possible to hang one only half an inch long and weighing from twenty to thirty grains by a fiber not more than a foot in length, so as to have a period of five minutes. If the moment of inertia of the heaviest beam of a certain length that the fiber will safely carry is so small that the period is too rapid, then the defect can be remedied by reducing the weight, for then a finer fiber can be used, and since the torsion varies approximately as the square of the strength (not exactly, because fine fibers carry heavier weights in proportion), the torsion will be reduced in a higher ratio, and so by making the suspended parts light enough, any slowness that may be required may be provided.

Practically, it is not convenient to use fibers much less than one ten-thousandth of an inch in diameter, and these have a torsion 10,000 times less than that of ordinary spun glass. A fiber one five-thousandth of an inch in diameter will carry a little over thirty grains.

Since with such small apparatus as I am now using it is easy to provide attracting masses which are very large in proportion to the length of the beam, while with large apparatus comparatively small masses must be made use of, owing to the impossibility of dealing with balls of lead of great size, it is clear that much greater deflections can be produced with small than large apparatus. For instance, to get the same effect in the same time from an instrument with a 6-foot beam that I get from one in which the beam is five-eighths of an inch long, and the attracting balls are two inches in diameter, it would be necessary to provide and deal with a pair of balls each 25 feet in diameter, and weighing 730 tons, instead of about 1¾ pounds apiece. There is the further advantage in small apparatus that if for any reason the greatest possible effect is desired, attracting balls of gold would not be entirely unattainable, while such small masses as two piles of sovereigns could be used where qualitative effects only were to be shown. Owing to its strongly magnetic qualities, platinum is unsuited for experiments of this kind.

By far the greatest advantage that is met with in small apparatus is the perfect uniformity of temperature which is easily obtained, whereas, with apparatus of large size, this alone makes really accurate work next to impossible. The construction to which this inquiry has led me, and which will be described later, is especially suitable for maintaining a uniform temperature in that part of the instrument in which the beam and mirror are suspended.

With such small beams as I am now using it is much more convenient to replace the long thin box generally employed to protect the beam from disturbance by a vertical tube of circular section, in which the beam with its mirror can revolve freely. This has the further advantage that, if the beam is hung centrally, the attraction of the tube produces no effect, and the troublesome and approximate calculations which have been necessary to find the effect of the box are no longer required. The attracting weights, which must be outside the tube, must be made to take alternately positions on the two sides of the beam, so as to deflect it first in one direction and then in the other. For this purpose they are most conveniently fastened to the inside of a larger metal tube, which can be made to revolve on an axis coincident with the axis of the smaller tube. There are obviously two planes, one containing and one at right angles to the beam, in which the centers of the attracting balls will lie when they produce no deflection. At some intermediate position the deflection will be a maximum. Now, it is a matter of some importance to choose this maximum position for the attracting masses, because, in showing the experiment to an audience, the largest effect should be obtained that the instrument is capable of producing; while in exact measures of the constant of gravitation this position has the further advantage that the only measurement which there is any difficulty in making, viz., the angle between the line joining the large masses and the line joining the small, which may be called the azimuth of the instrument, becomes of little consequence under these circumstances. In the ordinary arrangement the slightest uncertainty in this angle will produce a relatively large uncertainty in the result. I have already stated that if an angle of 45° is chosen, the distance between the centers of the large balls should be $2\sqrt{2}$ times the length of the beam, and the converse of course is true. As it would not be possible at this distance to employ attracting balls with a diameter much more than one and a half times the length of the beam, and as balls much larger than this are just as easily made and used, I have found by calculation what are the best positions when the centers of the attracting balls are any distance apart.

If the effect on the nearer ball only is considered, then it is easy to find the best position for any distance of the attracting mass from the axis of motion. Let P (Fig. 2) be the center of the attracting ball, N that of the nearer attracted ball, O of the axis of motion, c and a the distances of P and N from O, and x the distance from N of the foot of the perpendicular from P

on ON produced. Then the moment of N about O will be greatest when

$$x^2 + \frac{3a^2 + c^2}{a} x = 2(c^2 - a^2)$$

or, what comes to the same thing, when

$$\cos^2 \theta + \frac{c^2 + a^2}{ca} \cos \theta = 3$$

Now, as the size of the attracting masses, M M, is increased, or, as is then necessarily the case, as the distance of their centers from the axis increases, their relative action on the small masses, *m m*, at the opposite ends of the beams increases, and so but a small fraction of the advantage is obtained which the large balls would give if they acted only upon the small balls on their own side. For instance, if the distance between

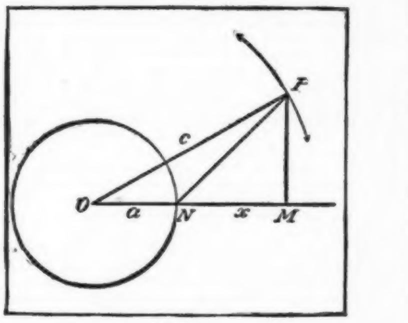


FIG. 2.

the centers of M M is five times the length of the beam, the moment due to the attraction on the opposite small balls is nearly half as great as that on the near balls, so that the actual sensibility is only a little more than half that which would be obtained if the cross action could be prevented.

I have practically overcome this difficulty by arranging the two sides of the apparatus at different levels. Each large mass is at or near the same level as the neighboring small one, but one pair is removed from the level of the other by about the diameter of the large masses, which in the apparatus figured here is nearly five times as great as the distance *in plan* between the two small masses.

In order to realize more fully the effect of a variety of arrangements, I have, for my own satisfaction, calculated the values of the deflecting forces in an instrument in which the distance between the centers of the attracting balls is five times the length of the beam, for every azimuth and for differences of levels of 0, 1, 2, 3, 4, and 5 times the length of the beam.

The result of the calculation is illustrated by a series of curves in the original paper. The main result, however, is this.

In the particular case which I have chosen for the instrument, *i. e.*, where the distance between the centers of M M and the axis and the difference of level between the two sides are both five times the length of the beam, as seen in plan, and where the diameter of the large masses is 6·4 times the length of the beam, the angle of deflection becomes 18·7 times as great as the corresponding angle in the apparatus of Cavendish, provided that the large masses are made of material of the same density in the two cases and the periods of oscillation are the same.

Having now found that with apparatus no bigger than an ordinary galvanometer it should be possible to make an instrument far more sensitive than the large apparatus in use heretofore, it is necessary to show that such a piece of apparatus will practically work, and that it is not liable to be disturbed by the causes which in large apparatus have been found to give so much trouble.

I have made two instruments, of which I shall only describe the second, as that is better than the first, both in design and in its behavior.

The construction of this is made clear by Fig. 3. To a brass base provided with leveling screws is fixed the vertical brass tube, *t*, which forms the chamber in which the small masses, *a b*, are suspended by a quartz fiber from a pin at the upper end. These little masses are cylinders* of pure lead 11·3 millimeters long and 3 millimeters in diameter, and the vertical distance between their centers is 50·8 millimeters. They are held by light brass arms to a very light taper tube of glass, so that their axes are 6·5 millimeters from the axis of motion. The mirror, *m*, which is 12·7 millimeters in diameter, plane, and of unusual accuracy, is fastened to the upper end of the glass tube by the smallest quantity of shellac varnish. Both the mirror and the plate glass window which covers an opening in the tube were examined, and afterward fixed with the refracting edge of each horizontal, so that the slight but very evident want of parallelism between their faces should not interfere with the definition of the divisions of the scale. The large masses, M M, are two cylinders* of lead 50·8 millimeters in diameter, and of the same length. They are fastened by screws to the inside of a brass tube, the outline of which is dotted in the figure, which rests on the turned shoulder of the base, so that it may be twisted without shake through any angle. Stops (not shown in the figure) are screwed to the base, so that the actual angle turned through shall be that which produces the maximum deflection. A brass lid made in two halves covers in the outer tube, and serves to maintain a very perfect uniformity of temperature in the inner tube. Neither the masses, M M, nor the lid touch the inner tube. The period of oscillation is 160 seconds.

With this apparatus placed in an ordinary room with draughts of air of different temperatures and with a lamp and scale such as are used with a galvanometer, the effect of the attraction can easily be shown to a few, or, with a lime light, to an audience. To obtain this result with apparatus of the ordinary construction and usual size is next to impossible, on account chiefly of the great disturbing effect of air currents set up by difference of temperature in the case. The extreme portability of the new instrument is a further advantage, as is evident when the enormous weight and size of the attracting masses in the ordinary apparatus are considered.

However, this result is only one of the objects of the present inquiry. The other object which I had in view was to find whether the small apparatus, besides being more sensitive than that hitherto employed, would also be more free from disturbances, and so give more consistent results. With this object I have placed the apparatus in a long narrow vault under the private road between the South Kensington Museum and the Science Schools. This is not a good place for experiments of this kind, for when a cab passes overhead the trembling is so great that loose things visibly move; however, it is the only place at my disposal that is in any degree suitable. A large drain pipe filled with gravel and cement and covered by a slab of stone forms a fairly good table. The scale is made by etching millimeter divisions on a strip of clear plate glass 80 centimeters long. This is secured at the other end of the vault at a distance of 1053·8 centimeters from the mirror of the instrument. A telescope 132 centimeters long, with an object glass 5·08 centimeters in diameter, rests on V's clamped to the wall, with its object glass 360 centimeters from the mirror. Thus any disturbance that the observer might produce if nearer is avoided, and at the same time the field of view comprises 100 divisions. While the observer is sitting at the telescope he can, by pulling a string, move an albo-carbon light, mounted on a carriage, so as to illuminate any part of the scale that may happen to be in the field of the telescope. The white and steady flame forms a brilliant background on which the divisions appear in black. The accuracy of the mirror is such that the millimeter divisions are clearly defined, and the position of the cross wire (a quartz fiber) can be read accurately to one-tenth of a division. This corresponds to a movement of the mirror of almost exactly one second of arc.

The mode of observation is as follows:

When all is quiet, with the large masses in one extreme position, the position of rest is observed and a mark placed on the scale. The masses are moved to one side for a time and then replaced, which sets up an oscillation. The reading of every elongation and the time of every transit of the mark are observed until the amplitude is reduced to 3 or 4 centimeters. The masses are then removed to the other extreme position and elongations and transits observed again, and this is repeated as often as necessary.

On the evening of Saturday, May 18, six sets of readings were taken, but during the observations there was an almost continuous tramp of art students above, producing a perceptible tremor, besides which two vehicles passed, and coals were twice shoveled in the coal cellar, which is separated from the vault in which the observations were made by only a 4½ inch brick wall. The result of all this was a nearly perpetual tremor, which produced a rapid oscillation of the scale on the cross wire, extending over a little more than 1 millimeter. This increased the difficulty of taking the readings, but to what extent it introduced error I shall not be able to tell until I can make observations in a proper place.

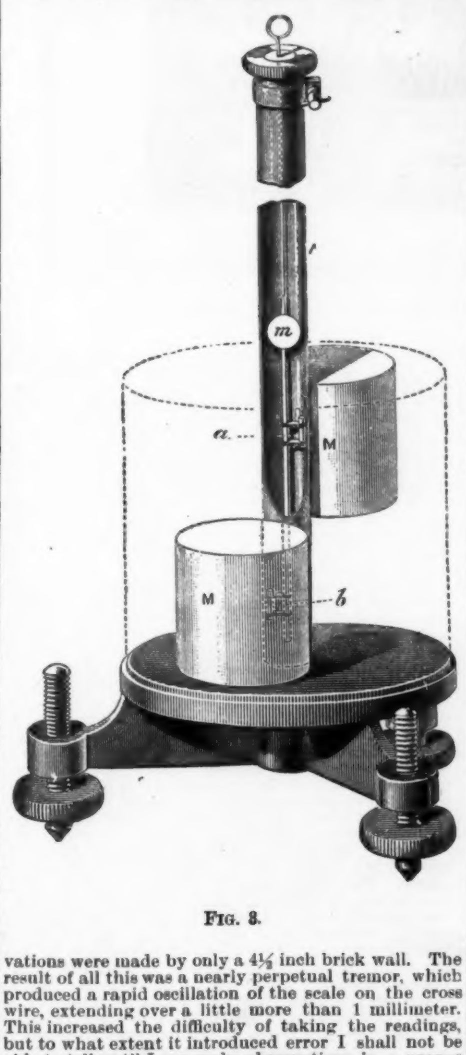


FIG. 3.

In spite of these disturbances, the agreement between the deflections deduced from the several sets of observations, and between the periods, is far greater than I had hoped to obtain, even under the most favorable conditions.

In order to show how well the instrument behaved, I have copied from my notebook the whole series of figures of one set, which sufficiently explain themselves.

Elongation.	Amplitude.	Decrement.	True position of rest.	Time of transit of 36·00.	Correction for transit of true position of rest.	True half period
				h. m. s.		
15·05						
53·20	38·15		36·18	9 8 25·0	+ 0·08	
22·48	30·72	0·805	36·20	9 45·5	− 0·18	80·2
47·28	24·80	0·808	36·21	11 5·8	+ 0·24	80·2
27·28	20·00	0·807	36·20	12 25·8	− 0·38	80·0
43·40	16·12	0·807	36·22	13 45·0	+ 0·41	79·9
30·42	12·98	0·805	36·21	15 6·0	− 0·47	80·1
40·88	10·46	0·806	36·22	16 25·0	+ 0·63	80·1
32·50	8·38	0·802	36·24	17 46·0	− 0·91	79·5
39·27	6·77	0·808	36·24	19 4·5	+ 1·13	80·5
32·80	5·47	0·808	36·26	20 27·0	− 1·58	79·8
38·25	4·45	0·814	36·26	21 44·0	+ 1·94	80·5
		0·8066				80·08

It will be noticed that the true position of rest is slightly rising in value, and this rise was found to continue at the rate of 0·36 centimeter an hour during the whole course of the experiment, and to be the same when the large masses were in positive or negative position. The motion was perfectly uniform, and in no way interfered with the accuracy of the experiments. It was due, I believe, to the shellac fastening of the fiber, for I find that immediately after a fiber has been attached, this movement is very noticeable, but after a few days it almost entirely ceases; it is, moreover, chiefly evident when the fiber is loaded very heavily. At the time that the experiment was made the instrument had only been set up a few hours.

The mean decrement of three positive sets was 0·8011, and of three negative sets, 0·8035. The observed mean period of three positive sets was 79·98, and of three negative sets, 80·03 seconds, from both of which 0·20 must be deducted as the time correction for damping.

The deflections, in centimeters, obtained from the six sets of observations taken in groups of three, so as to take into account the effect of the slow change of the position of rest, were as follows:

From sets 1, 2, and 3.............. 17·66 ± 0·01
" 2, 3, and 4.............. 17·65 ± 0·02
" 3, 4, and 5.............. 17·65 ± 0·02
" 4, 5, and 6.............. 17·65 ± 0·02

An examination of these figures shows that the deflection is known with an accuracy of about one part in two thousand, while the period is known to the 4,000th part of the whole. As a matter of fact, the discrepancies are not more than may be due to an uncertainty in some of the observations of one-half millimeter or less, a quantity which, under the circumstances, is hardly to be avoided.

The result of these experiments is complete and satisfactory. As a lecture experiment, the attraction between small masses can be easily and certainly shown, even though the resolved force causing motion is, as in the present instance, no more than the 1/200,000 of a dyne (less than 1/10,000,000 of the weight of a grain), and this is possible with the comparatively short half period of 80 seconds. Had it been necessary to make use of such half periods as three to fifteen minutes, which have been employed hitherto, then, even though a considerable deflection were produced, this could hardly be considered a lecture experiment. So perfectly does the instrument behave, that there can be no difficulty in making a fairly accurate measure of the attraction between a pair of No. 5 or, I believe, even of dust shot.

The very remarkable agreement between successive deflections and periods shows that an absolute measure made with apparatus designed for the purpose, but on the lines laid down above, is likely to lead to results of far greater accuracy than any that have been obtained. For instance, in the original experiment of Cavendish there seems to have been an irregularity in the position of rest of one-tenth of the deflection obtained, while the period showed discrepancies of five to fifteen seconds in seven minutes. The experiments of Baily, made in the most elaborate manner, were more consistent, but Cornu was the first to obtain from the Cavendish apparatus results having a precision in any way comparable to that of other physical measurements. The three papers published by him in the *Comptes Rendus* of 1878, referred to above, contain a very complete solution of some of the problems to which the investigation has given rise. The agreement between the successive values, decrement, and period is much the same as I have obtained, nevertheless the means of the summer and of the winter observations differ by about 1 per cent.

I have not referred to the various methods of determining the constant of gravitation in which a balance, whether with the usual horizontal beam or with a vertical beam on the metronome principle, is employed. They are essentially the same as the Cavendish method, except that there is introduced the friction of the knife edges and the unknown disturbances due to particles of dust at these points, and to buoyancy, without, in my opinion, any compensating advantage. However, it would appear that if the experiment is to be made with a balance, the considerations which I have advanced in this paper would point to the advantage of making the apparatus small, so that attracting masses of greater proportionate size may be employed, and the disturbance due to convection reduced.

It is my intention, if I can obtain a proper place in which to make the observations, to prepare an apparatus specially suitable for absolute determinations. The scale will have to be increased, so that the dimensions may be determined to a ten-thousandth part at least. Both pairs of masses should, I think, be suspended by fibers or by wires, so that the distance of their centers from the axis may be accurately measured, and so that, in the case of the little masses, the moment of inertia

* Cylinders were employed instead of spheres, because they are more easily made and held, and because spheres have no advantage except when absolute calculations have to be made. Also the vertical distance *a b* was for convenience made only about four times the length *a b* in plan.

of the beam, mirror, etc., may be found by alternately measuring the period with and without the masses attached. The unbalanced attractions between the beam, etc., and the large masses, and between the little masses and anything unsymmetrical about the support of the large masses, will probably be more accurately determined experimentally by observing the deflections when the large and the small masses are in turn removed, than by calculation.

If anything is to be gained by swinging the small masses in a good Sprengel vacuum, the difficulty will not be so great with apparatus made on the scale I have in view, *i. e.*, with a beam about five centimeters long, as it would with large apparatus. With a view to reduce the considerable decrement, I did try to maintain such a vacuum in the first instrument, in which a beam 1·2 centimeters long was suspended by a fiber so fine as to give a complete period of five minutes, but though the pump would click violently for a day perhaps, leakage always took place before long, and so no satisfactory results were obtained.

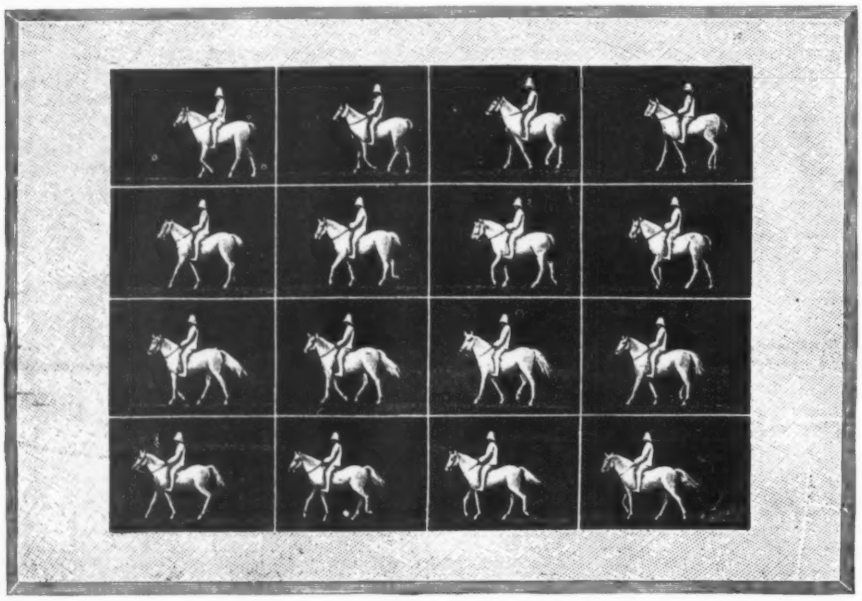
With an apparatus such as I have described, but arranged to have a complete period of six minutes, it will be possible to read the scale with an accuracy of 1/10,000 of the deflection, and to determine the time of vibration with an accuracy about twice as great.

I hope early next year, in spite of the difficulty of finding a suitable place to observe in, to prepare apparatus for absolute determinations, and I shall be glad to receive any suggestions which those interested may be good enough to offer. C. V. BOYS.

CHRONOPHOTOGRAPHY.

AMONG the new terms that were adopted by the first International Congress of Photography in 1889, that of "chronophotography," proposed by Mr. Marey, was received with the greatest favor for designating the processes and methods that permit of obtaining a series of photographic negatives at regularly determinate intervals of time.

The importance of chronophotography has no longer to be demonstrated. It suffices to recall that it is this art that permits us to analyze phenomena that take place so quickly that our eye cannot perceive the different phases of them.



MOTIONS OF A HORSE, PHOTOGRAPHED BY MR. MAREY.

Although the idea of constructing apparatus capable of giving a certain number of successive images occurred in the early days of photography, this new branch of the art did not come into vogue until the advent of gelatino-bromide of silver preparations.

The problem, that consists in obtaining a certain number of photographic images in a very short time and at definite intervals, is not so simple as might be thought, *a priori*, and various solutions have been proposed. It has seemed to us that it would be of interest to give a rapid review of these.

The first instrument to give accurate results was Mr. Janssen's photographic revolver—the apparatus with which our learned astronomer was enabled to obtain a series of negatives representing the different phases of the passage of Venus over the sun on December 6, 1874.

Mr. Janssen operated upon a circular plate that moved at regular intervals and presented the different portions of its surface at the focus of the objective.

Next, we may mention the remarkable labors of Mr. Muybridge, who was the first to apply photography to the study of motion in man and animals. Mr. Muybridge's method consisted in photographing the subject by means of a certain number of apparatus arranged in series. But this mode of operating did not, properly speaking, constitute chronophotography, for the dropping of the shutters did not occur at definite intervals, but was effected through the passage of the subject, who broke a series of electric wires placed in his path. We learn that Mr. Muybridge has since modified his arrangement, and can actuate his apparatus in a manner absolutely regular, and determined in advance. In France, Mr. Marey, struck by the results obtained by Mr. Muybridge, has taken up the subject, and given a series of methods which will henceforward be classical, and which have lent him powerful aid in his studies of animal mechanics.

Among the new apparatus devised by Mr. Marey, may be mentioned, in the first place, the photographic gun. This gave a dozen images per second upon a circular plate, and permitted the professor to pursue his first studies upon the flight of birds. But the size of the negatives was too small, and Mr. Marey quickly found, too, that the number of negatives taken per second was inadequate in many cases. So he struck out resolutely in an entirely new path. It was, in fact, impossible to increase the diameter of the sensitized plate, on account of the difficulty of putting this mass rapidly in motion. Moreover, as the image could not be formed upon the plate in motion, it became necessary, in order to obtain the requisite sharpness, to stop it at the precise moment of each exposure.

This series of abrupt stoppages and startings did not permit of taking any larger number of photographs per second. As a reminder, let us recall the fact that in the photographic gun the time of exposure in each case was but $\frac{1}{750}$ of a second, say $\frac{12}{750}$ for the dozen. The rest of the second, say $\frac{738}{750}$, was employed for the successive motions of the sensitized plate.

Abandoning this principle for a time, Mr. Marey indicates another and absolutely different method. Here the sensitized plate is immovable, and a disk with apertures, revolving rapidly in front of it, produces very rapid illuminations. The experiment is made in front of a perfectly black background, which reflects no rays capable of acting upon the preparation.

Consequently, although uncovered at every passage of the shutter, no impression will be made upon the plate. The model only, which stands out in white, and which, moreover, is brightly illuminated, will give a series of images that will be so much the more numerous in proportion as the revolution of the disk is faster or as the number of apertures is greater.

This method, as may at once be seen, obligatorily requires the motion of the model in a plane parallel with the sensitized surface. If the direction were at right angles or the motion were effected in place, the images would be superposed at the same place on the sensitized plate. If, even, the parallel motion were too slow, we should have the same inconvenience, but the images, instead of becoming superposed as in the preceding case, would encroach more or less upon one another. This is what happens in a slow motion, at the moment of reaching the earth after a jump. Mr. Marey has obviated this very ingeniously by reducing his model to the state of a line. To this effect he covers it with a black cloth from which stand out brilliant bands that mark the skeleton, while equally brilliant points mark the joints. The results thus obtained no longer present any confusion, and it is due to them that it has been possible to study the mechanism of walking, running, and leaping with the utmost precision.

Nevertheless, if it be desired to extend the analysis further, to examine the modifications of form in any motions whatever, and the play of the various muscles, the figures obtained in the preceding method are not capable of giving any information.

Mr. Marey therefore points out another method that permits him to obtain complete images, sharply defined, even though the subject does not move laterally, and even makes motions in place. This result is obtained by means of a plane mirror that revolves in front of the objective and spreads the images over the entire extent of the plate. The distance between the successive images depends upon the velocity of the mirror's rotation. This method therefore has the advantage over the preceding of giving absolutely disunited images. Moreover, each of these images may have all details desirable. Besides the general applications to the dissociation of any motion whatever, this apparatus has permitted of making original studies of the swimming of different fish or the walking of certain batrachians.

The different methods that we have just passed in review are utilizable only when it is a question of reproducing a larger subject, such as the horse, for example. The images forcedly overlap, and even on employing the arrangement that reduces the subject to the state of brilliant lines, the process is applicable only to the study of an isolated limb. So Mr. Marey, surmounting one by one the difficulties met by him, has finally presented an apparatus designed to give successive images of a horse in its entirety. He has taken up the idea of the photographic gun, but, instead of making use of a sensitized preparation on glass, he employs a thin film of light weight and great length. The preparation, wound upon a cylinder, passes to the focus of the objective; at this moment, a peculiar arrangement stops it while the shutter operates, and then it winds over a second cylinder. There were serious difficulties in the way of constructing this apparatus, on account of the necessity of arresting the sensitized preparation at the moment of every exposure. But the results reached are most conclusive and complete, for it is possible to obtain fifty images per second. Mr. Marey has kindly shown us a series of pictures of horses thus taken, and they are most remarkable (see figure).

Among other chronophotographic apparatus may be mentioned the photo-electric apparatus that we have had constructed for medical studies, and that of Mr. Anschuetz, who obtains fine results by using, like Mr. Muybridge, a series of photographic apparatus operated by electricity. Finally, Mr. W. G. Levison, in 1888, presented to the Brooklyn Photographic Academy a new apparatus provided with sensitized plates mounted upon a drum capable of carrying them rapidly, one after the other, to the focus of the objective.

From this study we can sum up perfectly the various processes that have been described for obtaining chronophotographic negatives. Some employ merely a photographic apparatus, and, thanks to the use of a perfectly black background, obtain a series of juxtaposed images upon the same plate.

Others cause the sensitized surface to advance abruptly and by jerks to the focus of the objective. The last make use of independent apparatus and as many of these as may be desired. It is not for us to determine which is the most preferable. We believe, in fact, that the one adopted should depend upon the character of the study undertaken. Yet it must not be ignored that it is with the apparatus that necessitate the black background that we obtain only the image of the subject, while with the others we obtain complete negatives with the different plans. In several respects this may be a serious advantage.

All is not yet probably said upon this very interesting question, and since Mr. Marey has described his last methods we have already been able to see other arrangements. Thus we remarked in the palace of the minister of war at the universal exposition a new apparatus.—*A. Londe, in La Nature.*

[PHARMACEUTISCHE RUNDSCHAU.]

ON THE CHEMICAL CONSTITUENTS AND POISONOUS PRINCIPLE OF THE BARK OF ROBINIA PSEUDACACIA, LINN.*

(*Common Locust or False Acacia.*)

By Professor Dr. FREDERICK B. POWER and JACOB CAMBIER.

IV. ANOTHER process was now followed for the extraction of the alkaloid, which is essentially that recommended by Brieger for the separation of choline from a mixture of ptomaines.*

Two and one-quarter kilogrammes of the bark were percolated with strong alcohol, and the greater part of the alcohol recovered by distillation. The residual liquid, separated from the deposited fatty matter, was then added to water to precipitate the resin, filtered, and the coloring and albuminoid matter separated as completely as possible by basic lead acetate. The filtrate from the latter precipitate, after being deprived of lead by hydrogen sulphide, was evaporated to the consistence of a thick extract, and the latter treated with absolute alcohol. To this alcohol solution was added an alcoholic solution of mercuric chloride, which produced a yellowish white, amorphous precipitate, becoming converted on standing into a sticky, brownish mass.

The precipitate so obtained was treated with successive portions of hot water, but, as nothing separated out on cooling,† the aqueous solution was treated with hydrogen sulphide to decompose the double salt of mercury with the alkaloid.

The clear, filtered liquid was then allowed to evaporate over sulphuric acid, but, as it did not crystallize readily, it was extracted with absolute alcohol and the alcoholic solution precipitated by an alcoholic solution of platinic chloride.

The precipitate produced by the latter was dissolved in water, and, on evaporation, afforded a few orange red prismatic crystals. These were dried at 110° C., and a platinum estimation made, with the following result:

0·1090 gramme of the salt gave on ignition 0·0340 gramme of platinum, or 31·19 per cent.

Calculated for $(C_5H_{14}NOCl)_2PtCl_4$	Found
Pt = 31·58 p. c.	31·19 p. c.

B. Distillation of the Bark with an Alkali.—500 grammes of the coarsely ground bark were extracted on a water bath with water acidulated with hydrochloric acid, the liquid strained and filtered, and evaporated on a water bath to a small volume. This was then mixed with milk of lime, and distilled. The distillate possessed a strongly alkaline reaction and a disagreeable, fishy odor. It was neutralized with hydrochloric acid, and evaporated to dryness on a water bath, the residue extracted first with ether alcohol (1:3), and afterward with absolute alcohol, the portion of the salt insoluble in the latter consisting of ammonium chloride.

The total amount of salt so obtained corresponded to 0·408 per cent. of the bark, of which 0·250 per cent. was ammonium chloride, and the remainder, or 0·158 per cent., considered as trimethylamine hydrochloride. The portions taken up by ether alcohol and strong alcohol, after the evaporation of the liquid, were again dissolved in alcohol, and precipitated by an alcoholic solution of platinic chloride. The precipitates were of a lemon yellow color, and, by crystallization from water, were obtained in the form of orange red prismatic crystals. Two estimations of the platinum in these compounds afforded 44·97 and 45·02 per cent. respectively.

Calculated for $N(CH_3)_3HCl \cdot PtCl_4$	Found I.	Found II.
Pt (194·4) = 45·01 p.c.	44·97 p.c.	45·02 p.c.

* Continued from SUPPLEMENT, No. 741, p. 11841.

† Fresenius' "Zeitschrift fur Analyt. Chemie." Vol. 26 (1887). p. 675.

‡ According to Brieger, "loc. cit.," the double salt of choline and mercury crystallizes out on cooling, while neurine and other bases remain in solution and the mercury compounds of albuminoid matters are not dissolved.

These platinum salts, therefore, agree with the hydrochloride of trimethylamine platinic chloride, and the solution from which they were prepared possessed all the physical and chemical properties of *trimethylamine*. The latter is undoubtedly produced by the decomposition of the choline, and possibly to some extent from the albuminoid matters, as is also the case when ergot is subjected to a similar treatment.

The choline under these circumstances splits into trimethylamine and glycol, as represented by the following equation:

$$\underbrace{OH-N(CH_3)_3-CH_2-CH_2-OH}_{\text{Choline.}} = \underbrace{N(CH_3)_3}_{\text{Trimethylamine.}} + \underbrace{\begin{array}{l} CH_2-OH \\ | \\ CH_2-OH \end{array}}_{\text{Glycol.}}$$

Since recent investigations have shown that choline is quite widely distributed, not only in plants belonging to the family of leguminosæ, but in others which are botanically widely separated therefrom, it would seem of interest and useful to other investigators to briefly indicate the hitherto observed sources, as well as some of the chemical characters and relationships of this interesting body.

The free base choline, known also as *sinkaline*, or *bilineurine*, possesses the empirical formula $C_5H_{15}NO_2$, and with reference to the molecular structure, is regarded as trimethyl-oxethyl-ammonium hydroxide,

$$N \left\{ \begin{array}{l} C_2H_4-OH \\ CH_3 \\ CH_3 \\ CH_3 \\ OH \end{array} \right.$$

Free choline, which is obtained by treating the hydrochloride with silver oxide, is generally described as a colorless, sirupy substance, having a strongly alkaline reaction, and uniting with acids to form neutral salts, which are mostly very deliquescent.

The solution of the hydrochloride, when allowed to evaporate over sulphuric acid in a rarefied atmosphere, affords deliquescent, needle-shaped crystals, but the platinum and gold double salts are especially characteristic.

The former of these gradually crystallizes from water in large orange red monoclinic prisms or plates, of the composition $(C_5H_{14}NOCl)_2PtCl_4$, while the latter forms small, yellow, needle-shaped crystals.

According to Wurz (Beilstein's "Handbuch der Organischen Chemie," p. 402), a concentrated solution of choline is decomposed on boiling into glycol and trimethylamine, and, by treatment with concentrated nitric acid, it is converted into the much more poisonous *muscarine*, $C_5H_{15}NO_3$.

In this connection it may be useful to call attention to the fact that in chemical literature choline is still frequently considered as identical with neurine, and this confusion of the two bodies serves to explain many discrepancies of statement.

Although closely related, it has been shown by Brieger,* Baeyer, and others that they do not possess the same chemical formula, and the difference in their physiological action is still more marked.

With regard to the occurrence of choline in the vegetable kingdom, we may mention that it has been found by Prof. R. Boehm,† in Marburg, to be abundantly contained in the fungi *Boletus luridies* Schaeff and *Amanita pantherina* D. C., and also appears to occur in the edible mushroom *Helvella esculenta* Pers. It was further found by the same investigator in the press cake of *cotton seed* and *beech nuts*, and a base separated by him from the human placenta also appears to be identical with choline. According to Harnack (see Beilstein's "Handbuch der organischen Chemie," p. 401), choline is found, together with muscarine, in *Agaricus muscarius* Lin. It has also been found in *hops*, and is therefore contained in beer (Griess and Harrow), in *hyoscyamus* and *belladonna* (Kunz‡), in *Indian hemp* and *hemp seed*§, in *fenugreek seed*‖, in *peanuts* (*Arachis hypogœa* Lin.) and in *lentils* (Jahns), in the *Ipecacuanha* and in the rhizome of *Acorus Calamus*, Lin. (Kunz), and, together with betaine, $C_5H_{11}NO_2$, in the seed of *Vicia sativa* Lin., or *Common Vetch*)¶.

A base isomeric with choline, but differing in some of its physical properties, has also been obtained by Brieger,** from ergot, as previously mentioned, and designated by him *iso-choline*. Choline has also been isolated by Brieger†† from human cadavers, and it therefore belongs to the class of so-called *ptomaines*. Indeed, Brieger‡‡ considers that in the first stage of decomposition of dead bodies choline is the only basic substance that occurs, but as decomposition progresses, other and more toxic ptomaines are also formed.

Although choline is sometimes stated to be nonpoisonous, more exact observations have repeatedly shown that this is not the case. Boehm,§§ for example, has proved by repeated experiments with frogs that in amounts of from 0·025 to 0·05 or 0·1 gramme, it produces in the course of from 10 minutes to one hour general paralysis, which in a remarkably short time results either in death or in the complete recovery of the animal. This indicates that the poison is either very rapidly eliminated or that it is changed within the organism. The same effects have been observed by Brieger,‖‖ who found 0·05 gramme of choline hydrochloride, when injected into a frog, to produce paralysis and a gradual diminution of the contractions of the heart, so that after about 1½ hours the latter remained motionless in diastole. The animal was again made to recover rapidly, however, by the injection of small amounts (0·001 gramme) of atropine.

These experiments prove that choline is a relatively mild poison, but in this connection the observation is important and interesting that under certain conditions it is readily converted into the much more poisonous *neurine*, $C_5H_{13}NO$. The latter substance, differing from choline, $C_5H_{15}NO_2$, simply by the elements of a molecule of water, has been stated by Liebreich* only to pre-exist in the protagon of the brain, but Prof. Schmidt† has shown that when hydrochloride of choline in aqueous solution is allowed to remain in contact with blood or with an infusion of hay for about 14 days at a temperature of 30–35° C. it is converted into neurine. This observation is believed to afford at least a partial explanation why perfectly normal fodders, containing choline, may suddenly acquire a poisonous action, and it is also deserving of consideration in all cases where plants containing choline are imputed with a specific physiological or toxic action.

The comparative physiological action, as well as the close chemical relationship of the three bases, choline, neurine, and muscarine, has been demonstrated in a most interesting manner by Dr. J. Lauder Brunton‡ in the Croonian lecture delivered before the "Royal College of Physicians of England," entitled: "Relation between chemical structure and physiological action." On this occasion Dr. Brunton has called attention to the structural composition of the three bases mentioned, as illustrative of the formation of a certain class of ptomaines, and has shown their relation to ammonium hydroxide by the fact that the members of this group may all be formed from trimethylamine and an alkyl radical in the same way as caustic ammonia may be regarded as formed from ammonia gas and water, as follows:

$$\underset{\text{Ammonium hydroxide}}{NH_4OH} \text{ or } H_3\equiv\overset{\overset{\displaystyle O-H}{|}}{N}-H = \underset{\text{Ammonia}}{H_3N} + \underset{\text{Water}}{H-OH}$$

$$\underset{\text{Neurine}}{C_5H_{13}NO} \text{ or } (CH_3)_3\equiv\overset{\overset{\displaystyle O-H}{|}}{N}-CH=CH_2 = \underset{\text{Trimethylamine}}{(CH_3)_3N} + \underset{\text{Vinyl alcohol}}{HO-CH=CH_2}$$

$$\underset{\text{Choline}}{C_5H_{15}NO_2} \text{ or } (CH_3)_3\equiv\overset{\overset{\displaystyle O-H}{|}}{N}-CH_2-CH_2-OH = \underset{\text{Trimethylamine}}{(CH_3)_3N} + \underset{\text{Glycol}}{HO-CH_2-CH_2-OH}$$

$$\underset{\text{Muscarine}}{C_5H_{15}NO_3} \text{ or } (CH_3)_3\equiv\overset{\overset{\displaystyle O-H}{|}}{N}-CH_2-CH(OH)_2 = \underset{\text{Trimethylamine}}{(CH_3)_3N} + \underset{\text{Hydroxyacetaldehydrol}}{HO-CH_2-CH(OH)_2}$$

An hydroxyl group thus passes from the alkyl to the nitrogen of the trimethylamine, and the residue also attaches itself to the nitrogen to form the respective base.

With regard to the physiological action of these bases, Dr. Brunton, *loc. cit.*, states that "they resemble one another very much, although varying enormously in their toxic power, muscarine being very much the more powerful; possibly, also, although this point is not at all settled, choline and neurine have a certain tendency to paralyze the motor nerves and muscles in somewhat the same way as curare, although this is not sufficient to interfere greatly with their other actions." He also states that the lethal dose of choline is ten times as great as that of neurine, and calls attention to the antagonism of atropine to these three alkaloids, since it paralyzes the identical nerve structures which are irritated by muscarine.

In connection with this subject we would also note the valuable investigation of Knorr§ on the molecular constitution of morphine, in which the close chemical relationship of the latter to choline is demonstrated. The derivatives of morphine which form the connecting links between these two bases are, however, of a complex character, and those specially interested may therefore be referred to the original publication.

C. Fermentation of Locust Bark.—In order to ascertain whether, through the fermentation of locust bark, neurine or other poisonous alkaloids might be formed from the choline therein contained, one kilogramme of the coarsely ground bark was covered with water and allowed to stand in a warm place for five weeks. At the expiration of that time the mixture had acquired an extremely disagreeable, putrid odor, but a sufficient amount of basic substances could not be obtained to determine their character.

D. Other Constituents of Locust Bark.—A portion of the bark was exhausted with boiling ether in a Soxhlet apparatus, when 2 per cent. of *fatty matter* and *resin* was obtained. A separate estimation of the resin made by allowing the fat to separate from the alcoholic extract, and then precipitating the latter by water, afforded 1·35 per cent. of this substance. The resin is soft, dark colored, soluble in ether, and also in solution of the alkalies, from which it is again precipitated on supersaturation with an acid. It possesses no special physiological action, since five grains of it administered to a cat produced no effect.

Sugar.—A portion of the bark was extracted with water, then heated to boiling to coagulate albuminous matter, and afterward treated with basic lead acetate to separate the remainder of the latter, as also *coloring matter*, *gum*, etc., and filtered. The filtrate, deprived of lead by hydrogen sulphide, was afterward treated with animal charcoal, then evaporated on a water bath, and finally over sulphuric acid. A light yellowish sirup was thus obtained, which, however, showed no tendency to crystallize. It does not reduce an alkaline solution of cupric oxide until after it has been heated with a mineral acid; 3·1105 grammes of it, dissolved in 50 cubic centimeters of water, when examined in a tube 200 millimeters in length, deviated the ray of polarized light 8° to the right. The same amount of pure cane sugar would have deviated the ray 27·7° to the right. On subsequent examination of the sugar it was found to still contain some albuminoid matter, and possibly also some other impurity. To obtain it in a purer form, it was subjected, after the above method of purification, to dialysis, by which means all albuminoid matter was completely separated, but the sugar was still associated with another substance, which may prove to be *asparagine*, as the latter body was long since shown to be contained in considerable amount in the root of the *Robinia Pseudacacia*).* There can be but little doubt that the sugar in question is *cane sugar*. A direction estimation of it as such, after inversion, by means of Fehling's solution, indicated the amount present in the air-dry bark to be 4·567 per cent.

A cold infusion of the bark, after being heated to boiling and filtering, affords a slight precipitate with alcohol, which, when collected, and redissolved in water, yields precipitates with basic lead acetate and ferric chloride, thus indicating the presence of small amounts of *gum*.

A decoction of the bark, when cooled and filtered, affords with iodine solution simply a brown coloration, which soon disappears. It was thus at first concluded that *starch* is absent, but the abundant presence of the latter was afterward demonstrated by the microchemical test. To what principle in the bark the decoloration of iodine solution by its decoction is due could not be determined, for the liquid was perfectly cold when tested.

E. ALBUMINOID SUBSTANCES.—Since none of the substances thus far isolated from the bark, including the very small amount of choline, could satisfactorily explain its reputed properties as an active poison, our attention was directed to the investigation of the albuminoid substances, which are present in exceptionally large amounts. This seemed the more important in view of the comparatively recent observations on the occurrence of protein† poisons in plants, especially in the so-called jequirity seed‡ (*Abrus precatorius*), in the papaw juice (from *Carica Papaya*), and in the seed of *Ricinus communis*.§

In the course of our investigation it was observed that if a cold infusion of locust bark be heated to boiling, a large amount of albuminous matter at once separates in the form of a white, flocculent precipitate, resembling the coagulated white of egg, and which can easily be removed from the clear liquid in which it is suspended by filtration.

By the application of the Kjeldahl process, the air-dry bark afforded 2·82 per cent. of nitrogen, and if this be calculated as albuminoid matter, with the use of the factor 5·25, the amount of the latter would correspond to 17·625 per cent. The amount of albumen coagulable by heat is, however, much less than the total amount present in the bark, for in a separate experiment the coagulated albumen, dried at 100° C., was found to represent but 3·2 per cent. of the air-dry bark.

The supposition that the poisonous action of locust bark might be due to an albuminoid body was further strengthened by the fact that a decoction made by boiling 100 grammes of the bark with water was taken by one of us (Cambier) in the course of 24 hours without experiencing any ill effect or any perceptible action. A cold infusion of the bark, on the other hand, was found to possess the violent action ascribed to it, and described in the first part of this paper. Such an infusion, representing 10 grammes of the bark, was taken by one of us (Cambier) at 10 A. M., with the subsequent production of a slight sensation of nausea; the same amount was taken at about 1 P. M. with a similar effect, and a third portion, taken at 3 P. M., produced after the lapse of 2 hours severe vomiting and purging. The total amount taken thus represented 30 grammes of the bark. On the following day a portion of the same infusion representing but about 5 grammes of the bark was taken (Power), and within about 2 hours a violent attack of vomiting and purging ensued, which continued at intervals for about 2 hours. A sense of dryness of the throat was also produced, and in fact all the symptoms of the poisonous action were precisely the same as those that have previously been described and which are recorded at the beginning of our paper. We were, therefore, able by our own unpleasant experience to fully corroborate the statements concerning the toxic action of the bark, and it would also appear from these experiments that in some individuals it acts with much more violence than in others.

Our attention being now directed to the separation of the active albuminoid, and to further test its action upon animals, two distinct processes were followed. The first of these was that corresponding to the preparation of the form of albuminoid which has been designated *globulin*, and the second to the so-called *albumose*.

I. *Globulin.*—500 grammes of the bark, in coarse powder, were digested for two days with two successive portions of a 15 per cent. solution of sodium chloride, and the liquid strained and filtered. The filtered liquid was then acidulated with acetic acid and saturated with sodium chloride, when, upon standing, a quite voluminous, flocculent, light brown precipitate was separated. The latter was subsequently subjected to dialysis until quite free from sodium chloride, which required about a week, and was then allowed to drain, spread on glass, and dried over sulphuric acid. When dry, it was obtained in the form of brownish-black scales, possessing a peculiar, disagreeable odor. The amount of this substance corresponded to 0·508 per cent. of the bark.

II. *Albumose.*—This was prepared by adding a cold, filtered infusion of the bark to an excess of absolute alcohol, when a quite voluminous, white precipitate was produced. This was filtered off, washed with a little alcohol, redissolved in water, and again precipitated as before. The product, after standing for some time in contact with alcohol, was collected on a filter, then spread on glass, and dried over sulphuric acid. This substance, when dry, forms light yellowish-brown scales, amounting to 1·66 per cent. of the bark.

Physiological Action of the Albuminoids.—Portions of the globulin were given to a kitten until finally an amount corresponding to 60 grammes of the bark had been taken, but no perceptible effect was produced. An amount of the albuminoid designated as albumose,

* "Untersuchungen über Ptomaine, I., pp. 31–39, and III., p. 14–17.

† "Archiv der Pharm.," 1886, p. 413.

‡ Ibid., 1885, p. 701.

§ Ibid., 1887, pp. 479–483 and p. 985.

‖ Ibid., 1887, pp. 985–997, and *Ber. d. deutsch. chem. Ges.*, p. 2518.

¶ Schulze, in *Ber. d. deutsch. chem. Ges.*, 1889, p. 1827.

** "Untersuchungen über Ptomaine," III., p. 107.

†† Ibid., II., p. 16, and *Berichte d. deutsch. chem. Ges.*, 1884, p. 2741.

‡‡ Ibid., II., pp. 17 and 34.

§§ *Archiv der Pharm.*, 1888, p. 413.

‖‖ "Untersuchungen über Ptomaine," III. p. 17.

* "Untersuchungen über Ptomaine," I., p. 32.

† *Pharm. Rundschau*, 1887, p. 286.

‡ *London Pharm. Journ.*, 1889, p. 1063.

§ *Ber. d. deutsch. chem. Ges.*, 1889, p. 1116, and *Pharm. Zeitung*, 1889, p. 303.

* Husemann's "Pflanzenstoffe." Second edition, p. 264.

† We use the term *protein* as synonymous with *albumen* or *albuminoid* bodies, in preference to the term *proteid*, which appears to be used with the same signification by some writers. According to Hoppe-Seyler ("Handbuch der physiologisch und pathologisch chemischen Analyse," 1883, p. 290), proteids are "bodies which *by their decomposition* afford albuminoid substances together with other bodies." (Körper, welche durch Spaltung neben anderen Stoffen Eiweissstoffe liefern.)

‡ Dr. Sidney Martin, in *London Pharm. Journal*, 1889, p. 197.

§ Ibid., 1889, p. 344.

corresponding to 10 grammes of the bark, was then given to a small dog, when a slight attack of vomiting was produced. Another portion of this albuminoid corresponding to about 30 grammes (or one ounce) of the bark was afterward given to a large dog. A severe attack of vomiting of mucous matter ensued within about 15 minutes, and although most of the substance appeared to have been ejected in the first act of emesis, the vomiting continued at intervals for about six hours, but was not accompanied by purging. No antidote was administered, and on the following day the animal appeared to have quite recovered.

In order to ascertain the action of heat upon this substance, a portion of it representing 20 grammes of the bark was dissolved in water, and coagulated by heating the solution to boiling. When given to a dog in this form it produced no effect, and an additional amount, prepared by simply heating the infusion, and representing 30 grammes of the bark, was also without effect. It was thus demonstrated that the toxic action of this albuminoid is destroyed at the temperature of boiling water, and readily explains why a decoction of the bark is devoid of activity, as we had previously shown.

With regard to the chemical and physical characters of this poisonous albuminoid, the following observations may be noted:

1. It is tasteless, soluble in water, and coagulated by heat, with complete loss of its former toxic properties.

2. Its solution, acidulated with acetic or hydrochloric acid, affords with potassium ferrocyanide a white, flocculent precipitate.

3. When heated with a solution of mercurous nitrate (Millon's reagent), it affords a purple-red precipitate; and when heated to boiling with a little solution of caustic soda, it affords on the subsequent addition of a drop of solution of cupric sulphate a purple-red color (Biuret reaction).

4. When dissolved in glacial acetic acid, and a little concentrated sulphuric acid is subsequently added, a handsome violet color is produced.

5. It is precipitated by solutions of potassium-bismuth iodide and tannic acid.

It will be observed that most of the above mentioned reactions are those common to albuminoid bodies as a class, but since the toxic albuminoid of locust bark differs on the one hand from the globulins in being readily soluble in water, and on the other from the peptones in being coagulated by heat, and being precipitated from its acidulated solution by potassium ferrocyanide, it would appear to be correctly and conveniently designated as a *phyt-albumose*. In thus designating it we are guided by the previous application of this term, as also by the classification of the albuminoids adopted by Hoppe-Seyler,* although the toxic substance separated in the same manner from jequirity seed by Dr. Sidney Martin,† and designated as *albumose*, is not precipitated from its solution by boiling.

We have not as yet determined whether the albumose of locust bark would act with greater intensity as a poison when introduced directly into the circulation of the blood by hypodermic injection than when taken into the stomach, although it is very probable that such would prove to be the case.

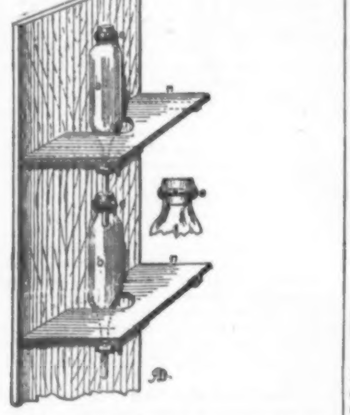
The intimate and extremely interesting relationship of the toxic vegetable albuminoids heretofore known to those of animal origin, such as the *venom of snakes*,‡ both colubrine and viperine; the *serum of the eel*, the conger eel and the muraena; and to the poison found in certain *spiders*, has been referred to in the valuable paper of Dr. Martin, *loc. cit.*, and it may, therefore, be but incidentally noticed here. It is to be regretted that no chemical reactions are as yet known by means of which these poisonous albuminoids can be distinguished from the larger number of those which are non-poisonous, and which represent so important a constituent of the food of animals.

In conclusion we trust that in having determined the character of the poisonous principle of locust bark, and thus adding one more to the list of toxic albuminoids, some slight contribution may have been made to both chemical and medical science.

University of Wisconsin, January, 1890.

A NEW CONTINUOUS EXTRACTOR.

MOST of the many apparatuses for making extracts are inapplicable when it is desired to make extracts of



UNGERER'S CONTINUOUS EXTRACTOR.

volatile substances, or of substances which would be decomposed by distillation or by warming. The annexed figure shows an arrangement by which the most concentrated extracts or tinctures of spices or perfumes, etc., can be made without evaporation. A number of cylindrical glass vessels, *a*, *b*, are placed on a suitable stand one above the other, so that the tube of one vessel passes through a cork fitted into the mouth of the vessel below. From six to twelve of these vessels may be used one above the other. The stand consists of a board with pairs of projecting pegs placed at such distances that there is room for the cylinders between them. Boards having a horseshoe shaped piece cut out on one side are placed on these pegs, and serve to support the cylinders in their places. The material from which the extract is to be obtained is placed in these cylinders, a little asbestos or cotton wool packing having been first inserted. The solvent is then allowed to run into the top cylinder, either freely or (in order to increase the pressure) through a long tube attached to the top. The liquid permeates the substance in the cylinder, and runs through into the cylinder below, and so on to the bottom, where it is drawn off as the strongest possible tincture. By adjusting the lowest stopcock, the speed of flow can be properly regulated. The number of vessels and the speed of percolating should be so regulated that the tincture begins to flow from the lowest cylinder just when the contents of the top one have been thoroughly exhausted. As soon as the top cylinder is exhausted it is removed, the whole column of vessels raised up a stage, and a newly fitted vessel is added at the bottom. In this way the process becomes continuous, and a concentrated extract can be made, except, of course, toward the end of the operation. When alcohol, ether, and similar solvents are used, the liquid remaining in the vessels at the end of the operation may be recovered by emptying the cylinders and distilling off the liquid from the spent material, or steam may be blown through the column from the top downward, when the spirit is driven out and may be collected below fairly well separated from the condensed water. Samples of the tincture may be taken at various stages by double boring the corks and attaching a tube with a stopcock, through which a portion of the extract may be drawn as required; or a three-way tap may be used with branch tube instead of the ordinary tap arrangement.—*A. Ungerer, in Zeitsch. f. ang. Chem.; J. Soc. Ch. Ind.*

* "Handbuch der physiologisch- und pathologisch-chemischen Analyse."

† *London Pharm. Journal*, p. 198.

‡ Dr. S. Weir Mitchell, in the *Century Magazine*, New York, Aug., 1889, pp. 503-514.

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